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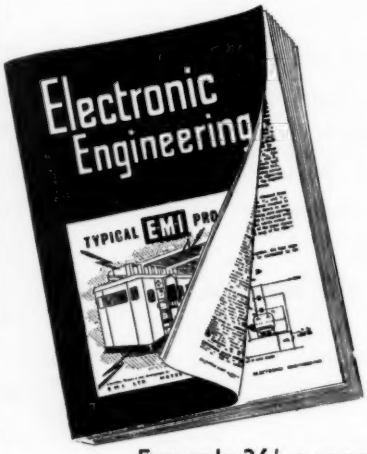

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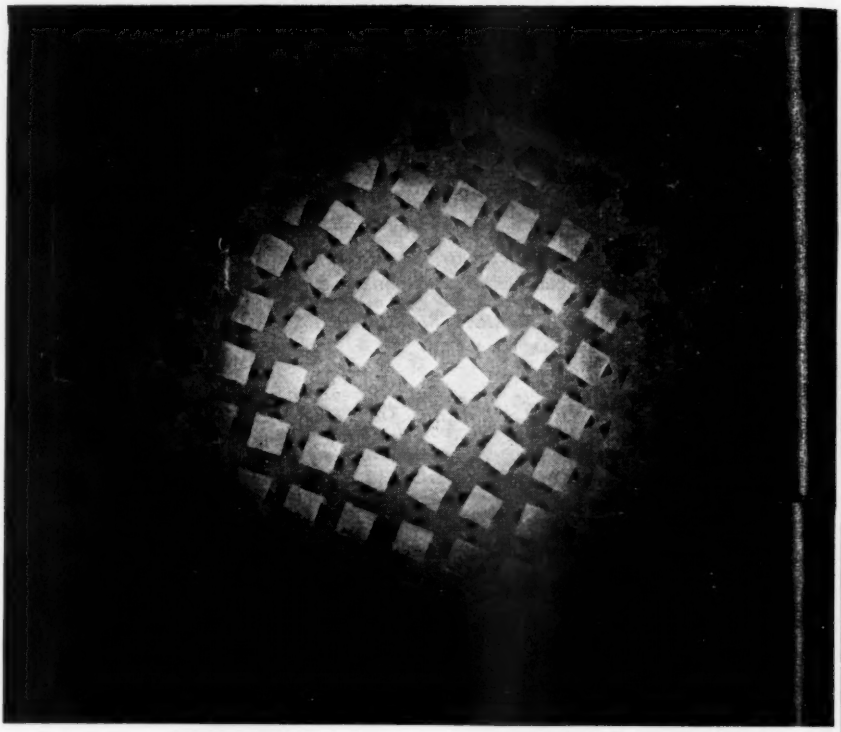

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THE BRONZE AGE PEOPLE OF YORKSHIRE: A GENERAL SURVEY[1]

by

D. R. BROTHWELL

Duckworth Laboratory, Museum of Archaeology and Ethnology, Cambridge

Introduction

During the past century, remains of over nine hundred uncremated Bronze Age skeletons have been located in Britain, and of these, six hundred have come from Yorkshire. Alas, remains of no more than four hundred still remain in our museums, usually only as skulls, the rest of the bones having been thrown away as of little value.

Although a number of earlier physical anthropologists have concerned themselves with some of these specimens, the published information on Bronze Age man is still far from what is to be desired, and for this reason I have recently examined many of the specimens in various museums, in the hope of providing a more complete picture of man during this prehistoric period. The purpose of this article is to give a brief general review of one part of this British group, namely, the population of Yorkshire, though owing to the inadequacy of the material when studying certain features, I have at times found it necessary to combine the information with that for Bronze Age man in other parts of Britain.

It should be noted that for the purpose of this study, the Bronze Age people of Yorkshire will be considered as a whole, even though for certain physical features they show a divergence of type indicative of quite a mixed population. The most thorough previous study of Bronze Age man, undertaken by G. M. Morant in 1926, did not include all the skulls of this period. On the assumption that the dolichocephalic section of the group were in fact the indigenous Neolithic inhabitants, he ingeniously separated a fairly 'pure' brachycephalic group from them and from the possible hybrids. However, the assumption that the Beaker invaders who landed on the Yorkshire coast and other parts of Britain were purely brachycephalic does not appear valid when considering the amount of variability to be seen in Late Neolithic peoples of the Danish and French regions. In other words, the Bronze Age population of Yorkshire was probably far more of a mixture than previously suggested.

Most of the skeletons from the Yorkshire barrows are, by their associated remains, clearly of Early Bronze Age date, and therefore the physical type discussed here may not represent the whole of the period. Indeed, there is every reason to believe that by the end of the Bronze Age a more homogeneous population had evolved, which as Howells (1937) suggests, no doubt played an important part in determining the physique of Iron Age man.

Mortality

One of the first questions we ask ourselves about earlier people is how many of them survived into adulthood, or for that matter, old age. An estimate of the mortality of this Yorkshire population is unfortunately difficult to arrive at. In some previous studies on earlier populations, mortality frequencies have been

[1] Paper delivered to Section H (Anthropology) on September 7, 1959, at the York Meeting of the British Association.

given for various age-groups from infancy into adult life. However, much of the earlier work on ageing adults relied upon the degrees of obliteration of certain skull sutures, but this procedure is now known to be unreliable. For the purpose of this study therefore, I intend only to separate adults from non-adults, the distinguishing line being 21 years, as judged from skeletal development.

In Fig. 1 the percentage frequencies of these two broad age-groups are given for various ancient and modern peoples, including the Yorkshire Bronze Age

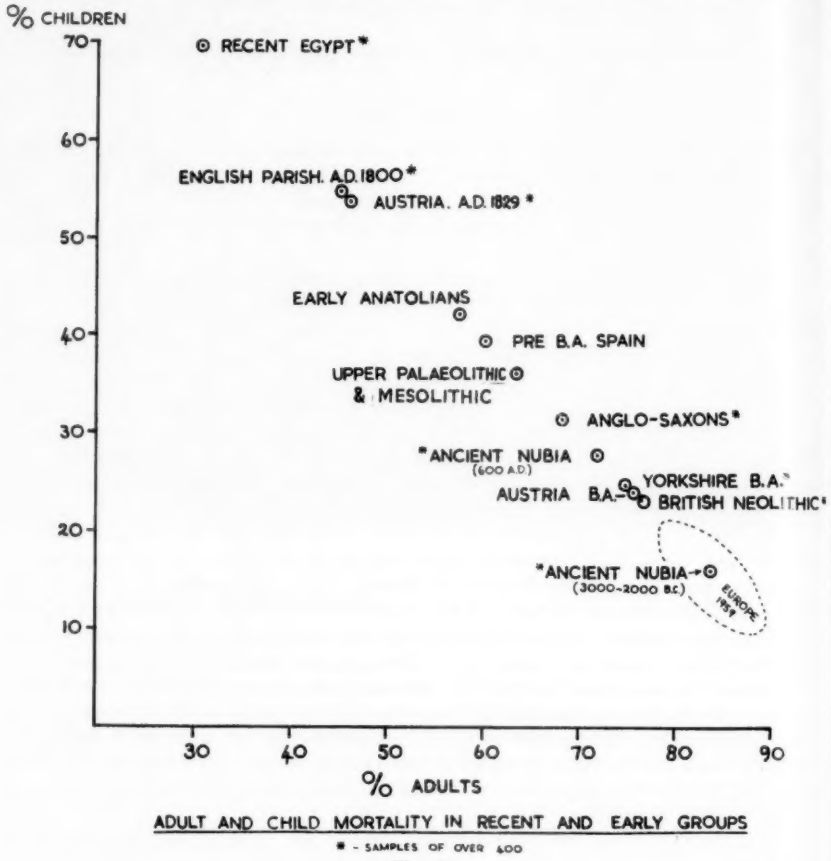


Fig. 1.

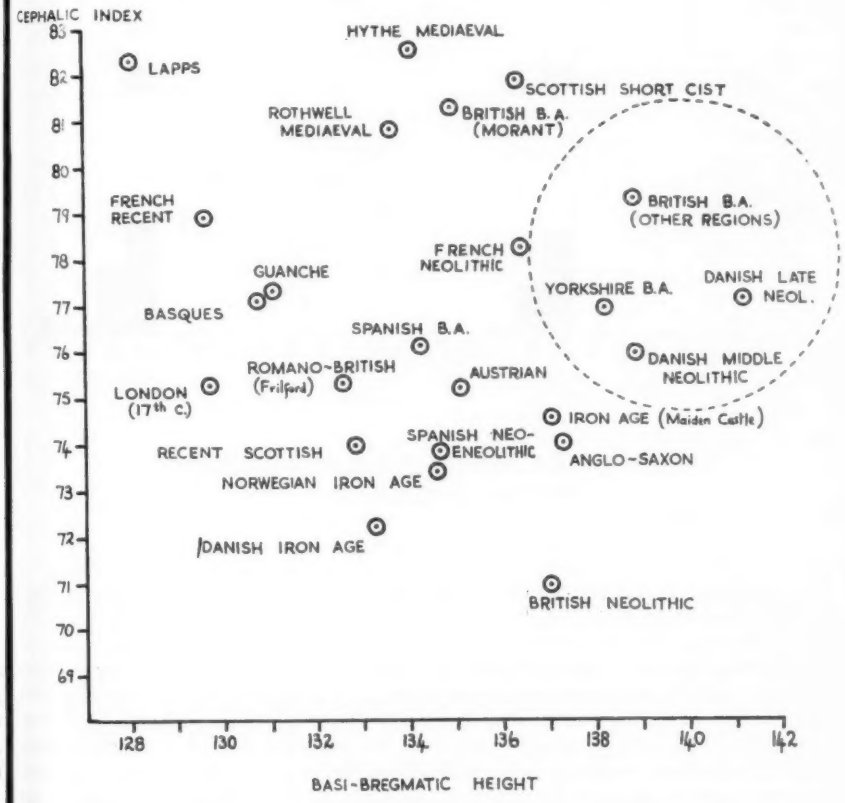
sample. The result is not what I had expected, for none of the earlier populations shows a particularly high infant mortality. It is generally considered, of course, that infant deaths in such groups would be at least as high as the British or Austrian groups at the beginning of the nineteenth century or the recent Egyptians, but none of them is near these, and indeed, they seem to be grouped more towards the present-day European frequency.

Obviously, the skeleton of a child is more likely to disintegrate in soil than a more robust one, and this post-mortem selection no doubt accounts for some discrepancy. Also, although infants have been found in Yorkshire barrows, both as primary and secondary burials, burial practices may nevertheless account for their scarcity to some extent. But surely the fact that relatively low infant percentages

are found in all these earlier groups could suggest a third reason. Perhaps we forget that, although early man may have led a somewhat rigorous life, he probably did not 'enjoy' the wide variety of diseases of modern man. We know from recent studies that poor sanitary conditions are not sufficient in themselves to cause much ill-health. Moreover, it is possible that many of the known killers of man today, such as smallpox, leprosy, and diphtheria were not known to the Bronze Age inhabitants of Yorkshire. Without further speculation then, it seems likely that these early Yorkshire people need not have had a high infant mortality, although obviously this can only be a tentative conclusion.

The Skull

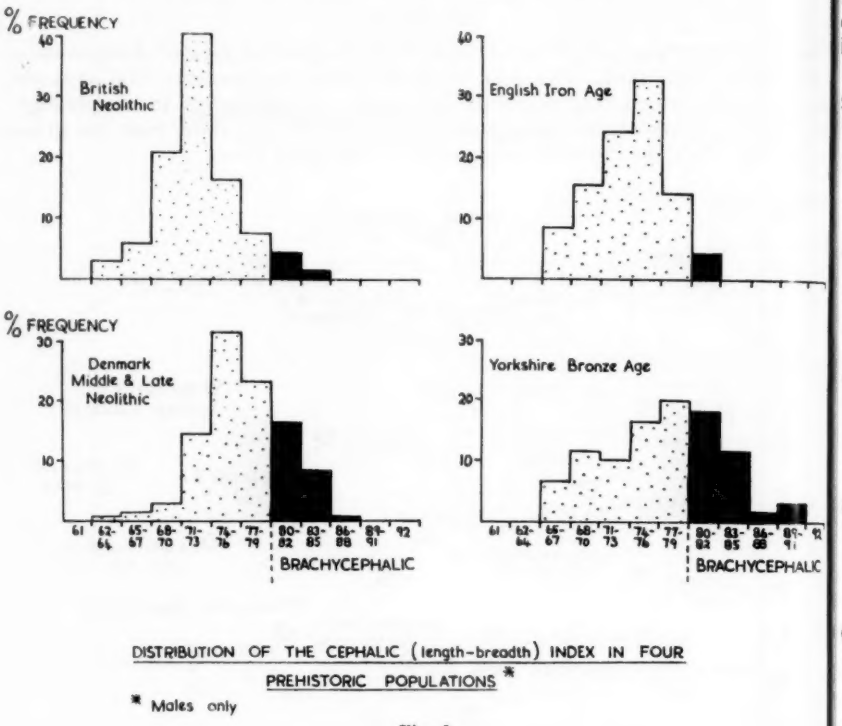
The most important part of the skeleton from the point of view of distinguishing earlier man is the skull. This may be considered in two respects; first as to the measurements which help to record accurately any differences in morphology; secondly as regards certain non-metrical features which may differ from one group to another. Only the metrical features will be discussed here.



THE AFFINITIES OF THE YORKSHIRE BRONZE AGE POPULATION WITH OTHER GROUPS, USING THE CEPHALIC INDEX AND VAULT HEIGHT. (Males only)

Fig. 2.

Some of the Yorkshire skull dimensions show noticeable differences from earlier and later skull series. This is easily demonstrable by comparing three major vault measurements, length (L), breadth (B), and height (H'). In Fig. 2, we see the distribution of some earlier peoples about the Yorkshire group, according to the cephalic index $\left(100\frac{B}{L}\right)$ and vault height (H'). It is interesting to note that the Yorkshire people are especially close to the Danish and French Neolithic groups. The general British Bronze Age series (from other regions) is very similar to the Yorkshire group in vault height but has a much higher cephalic index.



DISTRIBUTION OF THE CEPHALIC (length-breadth) INDEX IN FOUR PREHISTORIC POPULATIONS *

* Males only

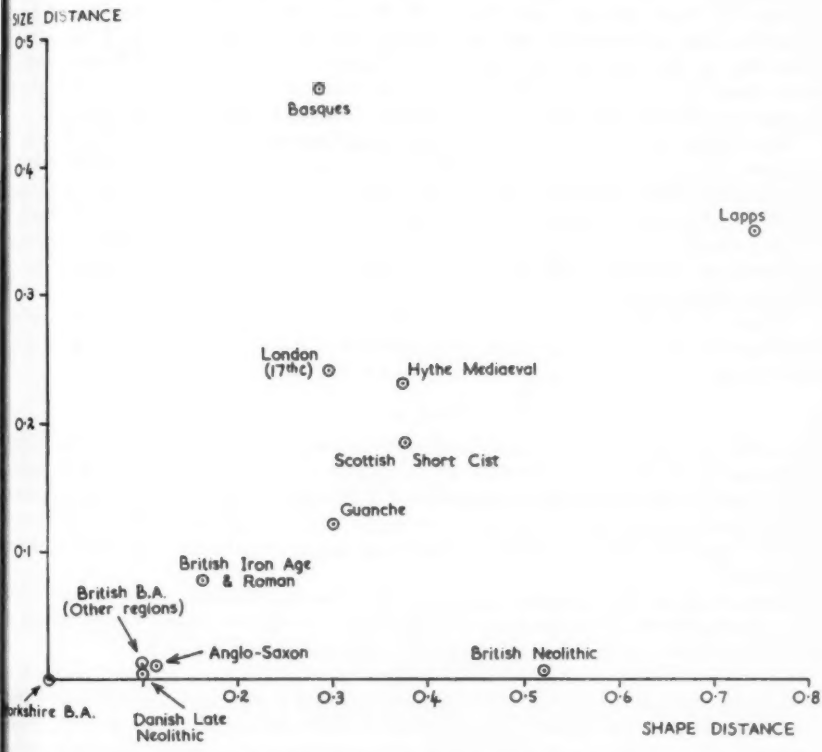
Fig. 3.

A consideration of the distribution of the cephalic index in a number of these groups gives us a better idea of the frequency of brachycephaly. Fig. 3 shows the distribution for the Yorkshire group in comparison with the British Neolithic, English Iron Age and Danish Neolithic. Of these, the Yorkshire and Danish series included similar percentages of brachycephalic individuals. Moreover, they both show a very wide range in their indices, a feature which is also found in French and Belgian Neolithic people. Clearly then, although the British Neolithic inhabitants showed little tendency towards brachycephaly, it was much more frequent and was perhaps even on the increase, in some northern European areas at the close of the Neolithic.

A consideration of a larger series of measurements together gives a more accurate picture of the affinities of the Yorkshire group with others. To make a comparison I have used a statistic devised recently by Prof. Penrose (1954). This distance statistic may be split into two components which he calls size and shape, the first

being concerned with the overall skull size while the shape distance considers the morphology of the skull.

In Fig. 4, the Yorkshire males are represented at the origin of the size and shape scales, and plotted at varying distances are the affinities of eleven other groups. As expected, the other British Bronze Age peoples are very close, and the same is true of the Danish Late Neolithic. This latter similarity is supported by the other craniometric evidence, and, as far as the skull features are concerned it is clear that the physical type existing in Denmark at the close of the Neolithic period closely resembled, if it did not partly give rise to the Yorkshire Beaker immigrants. This is not to say that the Danish group did not undergo some change in its development on the Continent, and indeed, considering the cultural movements taking place in Europe at that time, an appreciable degree of intermixture is to be expected.



DISTANCES OF ELEVEN RECENT AND EARLIER PEOPLES FROM THE YORKSHIRE BRONZE AGE GROUP. BASED ON TEN SKULL MEASUREMENTS. (MALES ONLY)

Fig. 4.

Stature

The stature of Bronze Age man was estimated from the lengths of long bones as early as 1870 by John Thurnam. His estimates of about 5 ft. 8½ in. for Bronze Age man and nearly 5 ft. 5½ in. for the Neolithic peoples were later challenged by Mortimer (1877), who, on the evidence of Yorkshire material, thought the Neolithic type to have the greater stature.

In view of the small samples used in these earlier estimates, and the rough

nature of the formulae by which stature was estimated, it has been necessary to collect more data and apply modern statistical methods. The number of Yorkshire males available was unfortunately only thirty-five, giving a mean stature of nearly 5 ft. 7½ in. Too few females were available to warrant a height estimate in their case. A larger male series of seventy-eight from the rest of Britain gave a mean height of 5 ft. 8½ in., and, combining both of these, we get a far more reliable estimate for Bronze Age man of just over 5 ft. 8 in., which is remarkably similar to Thurnam's rough figure.

For comparison I was able to estimate a mean stature of 5 ft. 5¾ in. for British Neolithic man (sixty-eight males) and another of 5 ft. 6½ in. for the combined Iron Age and Roman peoples (eighty-eight males). It would appear, therefore, that Yorkshire Bronze Age man, like his other British contemporaries, was taller than the immediately earlier and later groups. The reason for this height increase during the early Bronze Age may well be explained by the evidence of Late Neolithic man in Denmark, who had a mean stature of over 5 ft. 9 in. I might add here that in the case of four long bone diameters also, the early Yorkshiremen were found to resemble far more closely the other Bronze Age Britons and these Danish Neolithics than they did the British Neolithic and Iron Age groups.

This difference between the Yorkshire and Danish heights could be due to a number of factors. First of all, the samples are still not as large as could be desired for very accurate statistical work; secondly, mixing of the invaders with the smaller indigenous inhabitants of Yorkshire would tend to reduce the average height; thirdly, the very fact that the group had moved to a slightly different environment, perhaps with variations in food supply, could have caused minor changes in physique.

Stature, I think, is perhaps not the best feature by which to compare earlier populations, but this sort of data is nevertheless of some value in conjunction with other facts.

The Teeth

The state of health of the teeth and jaws of earlier man can provide revealing information for the anthropologist as well as for the dentist, and indeed it is one of the most frequent indicators of disease to be found in his skeleton. The common pathological changes which take place in the jaws can to a great extent be attributed to diet, especially the carbohydrate foods, as well as to the general health of the individual.

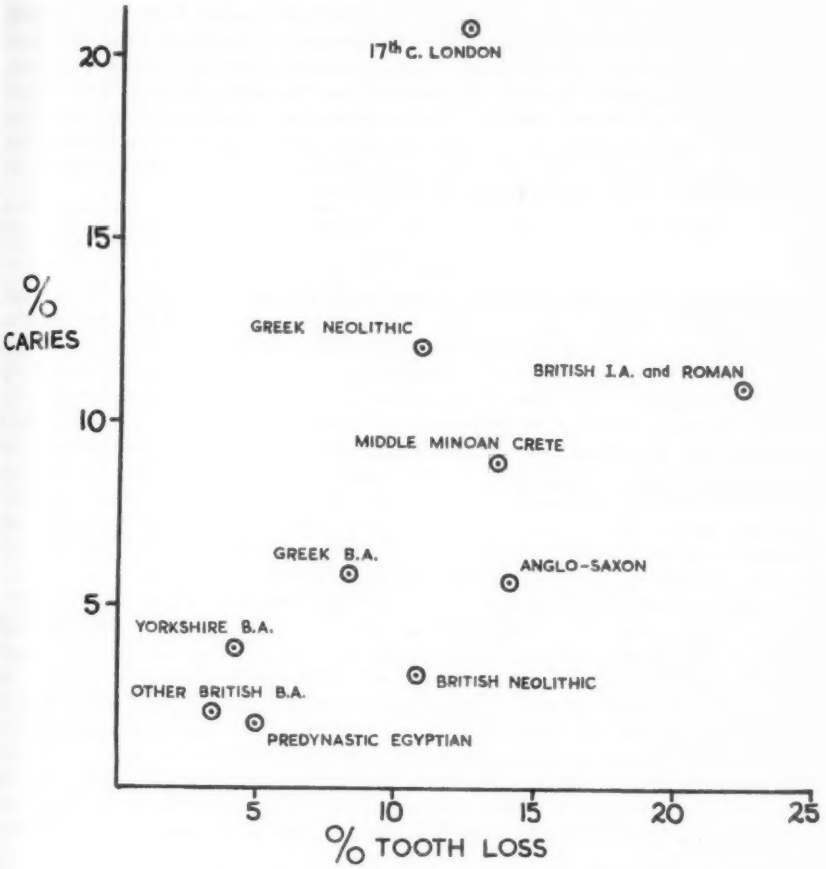
In the case of the Yorkshire group, I have been able to examine about 3,500 adult teeth, which provide a fairly reliable estimate of their dental health. Most of the comparative frequencies were calculated from smaller samples.

Considering first ordinary dental decay (caries) and ante-mortem tooth loss which together give us some idea of the total dental disease, it is worth noting that the Yorkshire group and the general Bronze Age series both show very low frequencies (Fig. 5). Except for the Predynastic Egyptians, the other early comparative series have higher frequencies. There is no doubt that these differences are mainly the result of the interaction of culture and diet. If, as Prof. Childe (1949) suggested, the Beaker folk were even more pastoral than their precursors, then this may well explain the improvement in dental health at the end of the British Neolithic period, for peoples with high protein diets are far less susceptible to such troubles.

Unlike the frequencies just mentioned, jaw abscesses did not increase much in occurrence from Neolithic to recent times, and in the Yorkshire group, just over 2 per cent of the tooth sockets showed abscess cavities.

Abnormal development of the enamel (enamel hypoplasia) on the crowns of teeth also yields interesting information. We know that this condition is usually caused by disease or nutritional disturbance during tooth development, and, in the

case of a large frequency within a population, diet is most likely to be the responsible factor. Of 131 Yorkshire skulls examined for this enamel condition, just over 50 per cent showed it, at least to a slight degree. Such prevalence, I think, can only point to the fact that many of these people suffered from periodic malnutrition, in any case during childhood.



CARIES AND TOOTH LOSS IN TEN EARLIER GROUPS

Fig. 5.

Osteo-arthritis

One form of rheumatic disease known as osteo-arthritis, produces easily detectable bony changes. Some forms of this osteo-arthritis are probably associated with mechanical stresses imposed upon the joints, while other types may be genetically as well as environmentally determined. Unfortunately so few post-cranial remains have been saved that I have so far been able to examine only thirty fairly complete Bronze Age skeletons which show arthritic changes, and these are from various parts of Britain. However, as the results are no doubt typical of Bronze Age Yorkshiremen, some comment is worth making here. In the small series available

to me it was found that the vertebrae were most affected (mainly in the form of 'lipping' on the vertebral bodies), the lumbar region being the most commonly involved, the thoracic to a lesser extent, and the cervical the least. For comparison, fifty other cases, dating from the Iron Age to the Anglo-Saxon period, were examined; and again, the thoracics and lumbars are the vertebrae most affected, each roughly to an equal degree, but the cervicals are freer from osteo-arthritis in this series than the other bones of the skeleton. Judged from data recently given by Dr. Stewart of the U.S. National Museum, a sample of modern Whites show far more cervical arthritis than is found in the early British material; moreover, Dr. Stewart also noted the same difference when comparing the American Whites with Eskimos and Pueblo Indians. This suggests that regional arthritis can differ in severity from one group to another, as regards either earlier or modern peoples. In the case of Bronze Age and other early British material, larger samples are needed before a more detailed analysis can be made.

Other Disease

As well as the relatively common diseases such as tooth decay and rheumatism, the Yorkshire Bronze Age material has provided three unique pathological specimens, now a part of the Mortimer Collection of Hull Museum. Only one of these has so far received suitable description. This is an unusual case of hip dislocation, Plate 1 (*a*), already described by an American anthropologist Dr. Ashley Montagu (1932). The individual to whom it belonged, a man, was found in barrow 27, near Thixendale. Some years before his death, the right femur had been displaced downwards and a new socket had formed below the normal. Associated with this deformity are rheumatic changes, and the movement of bone-on-bone caused the femur head to become eroded and polished during life. Surprising as it may seem, the evidence clearly shows that its owner was still able to move on this leg, although it was slightly longer than its fellow.

The second specimen is the skull from burial P, barrow 118, one of the Painsthorpe Wold group. The individual concerned is an adult male, and his skull shows a remarkable swelling along much of both sides of the coronal suture (Plate 1 (*b*)). This ends on the right side of the frontal bone in the region of an extensive fracture of the vault. The reason for such a bony mound is not easy to find. The fact that the bone thickening is so restricted makes it unlikely that rickets or severe anaemia is the cause. The most likely explanation seems to be that it is the result of a haematoma, produced by a blow or blows in that region, causing a considerable amount of blood to collect under this part of the scalp. The final result of this injury was the formation of new bone at the site of the congested blood.

The third specimen was found in barrow 23 of the Calais Wold group (Plate 1 (*c*)). Mortimer (1905) noted that the individual was an adult male and that: 'All the bones of the left hand . . . are joined together (anchylosed), and are also united to the radius and ulna. The finger bones, however are free.' Actually, only the radius now remains united to the carpal (wrist) bones, the ulna having broken away and been lost. The man had evidently received an extensive wound at the wrist, resulting in noticeable deformity. The bones and joints of this area became infected, and although some healing has taken place, a number of depressions represent continuing pockets of infection.

Conclusion

From this brief survey of Bronze Age Yorkshiremen, we may conclude then that the group is of somewhat mixed physique, especially as regards skull features.

They were, however, very similar in appearance to Bronze Age men in other regions of Britain, and they also had close affinities with the late Neolithic population of Denmark, from which they may have originated.

Acknowledgements

Grateful thanks are due to Dr. J. C. Trevor for offering helpful criticisms; and Dr. A. M. Barrett with whom I discussed the rare pathological conditions. I should also like to thank Mr. John Bartlett, Director of Hull Museums, and Dr. K. P. Oakley, F.B.A., of the British Museum (Natural History), who gave me access to much of the Bronze Age material.

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PLATE I (*a*). An unusual hip dislocation. The arrow points to the normal socket for the femur head.

PLATE 1 (*b*). The skull from barrow 118. The arrow points to the fractured area, and the dotted line shows the extent of the swelling.

PLATE I (*c*). The diseased wrist of the man from barrow 23.

PEAT EROSION IN THE PENNINES[1]

by

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Introduction

Peat bogs have developed extensively in the Pennines, on most of the flat and gently sloping ground above 1,300–1,500 ft. (O.D.), where the average rainfall exceeds 40–50 in. a year. Over very large areas the peat is now being eroded by gullies which develop into and within the peat blanket (i.e. dissection), together with mass movement of peat on many of the slopes.

The Development and Distribution of Blanket Peat Bogs in the Pennines

The peat has accumulated in some places since the Boreal-Atlantic transition of about 6000 B.C., but the area and the rate of accumulation probably increased markedly as a result of the climatic deterioration of the Sub-Atlantic period starting about 500 B.C. (1, 2). The peat bogs in the Pennines are mainly blanket bogs. The peat is acid or bog peat and these bogs are so named because they are said to lie like a blanket over the whole country—on flats, slopes, hollows and summits alike. This is because the waterlogging necessary for peat to form is due to high rainfall or, more precisely, to a high precipitation/evaporation ratio. This is the basic factor behind the development and distribution of blanket peat bogs, which are thus confined to areas of high rainfall; they are present in many upland areas and in lowland areas in northern Scotland and western Ireland. The Pennines afford an example of the upland areas; here the peat has only developed in areas which now have at least 40–50 in. of rainfall a year. Eighty inches is about the maximum average annual rainfall in the Pennines. The rainfall is generally adequate above 1,300–1,500 ft. (O.D.).

In addition, other secondary factors of landform and geology operate within the climatic limits to determine the detailed distribution, and the type and depth of peat. Landform operates largely through the influence of ground slope on surface drainage. Geology operates through its influence on relief and on the soils developed prior to peat formation. Soils developed on gritstone are coarse and acid and more readily become leached, develop a pan, and become the sites of bog development than soils on, for example, limestone. These three are also the main factors in peat erosion. The various types of erosion and the stages reached in erosion at the present time may be interpreted in relation to these factors.

The Distribution of Blanket Peat Bogs and Peat Erosion in the Pennines

The distribution of peat and of active peat erosion in the Pennines have been mapped from aerial photographs in association with ground survey—the final maps being produced on a scale of 1 in. to 1 mile. The erosion systems were plotted from 1:10,000 vertical photographs on 1:25,000 Ordnance Survey maps, which were reduced to make the final maps. A sample taken from these maps is reproduced in Fig. 1.

[1] Paper delivered to Section E (Geography) on Wednesday, September 9, 1959, at the York Meeting of the British Association.

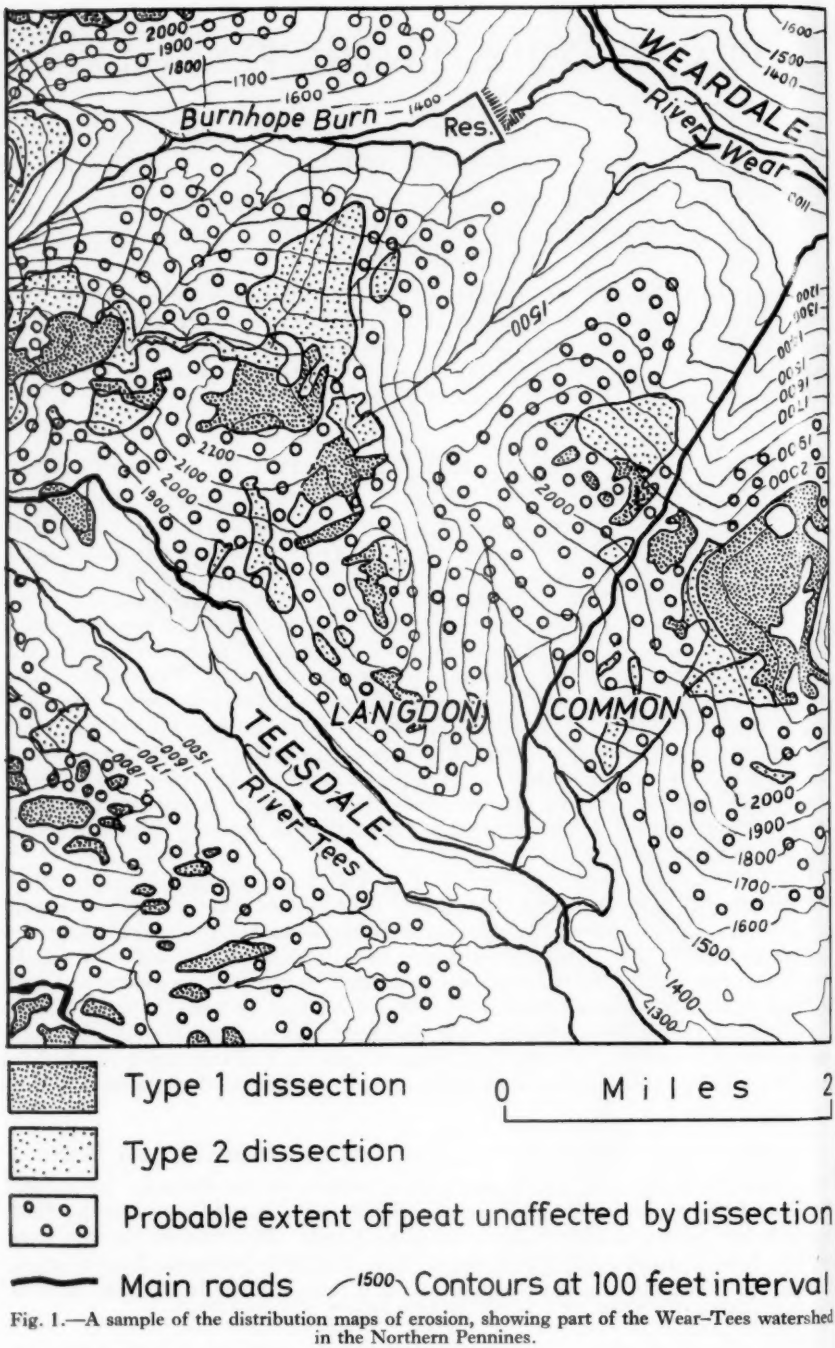


Fig. 1.—A sample of the distribution maps of erosion, showing part of the Wear–Tees watershed in the Northern Pennines.

In the Pennines the *peat* is deeper the higher the rainfall at the present time. As rainfall generally increases with altitude, the peat is deepest in the highest and wettest areas. The peat is also deeper the flatter the ground. Even in the highest rainfall areas it is rare on slopes exceeding 20°, such a slope being adequate to maintain surface drainage and so prevent peat formation. As rainfall decreases, so does the limiting slope for peat formation. Peat is often absent from limestone outcrops, except where they are covered with drift. The depth varies from 2 ft., which is taken as the lower depth limit for peat, up to about 10 ft.; this is rarely exceeded although a few deep pockets in depressions exceed 30 ft.

In the Pennines *peat erosion* now occurs most frequently, and intensively, and is usually most advanced, in the deeper peats of the higher and wetter areas. Generally, one may say that above 1,800 ft. the peat is very deep and severely eroded; here it usually exceeds 6 ft. in depth on the flats and may be up to 5 ft. deep on slopes of up to 20°. Between 1,500 and 1,800 ft. it is moderately deep and often eroded and depths of up to 6 ft. are fairly common on flat ground. Below this the peat is not usually deep or dissected.

The Nature of Erosion in Blanket Peat

Five types of erosion systems have been distinguished on the basis of differences in the forms and patterns of the features resulting from erosion, which can be seen both on the air photographs and on the ground. These are in addition to more obvious contrasts due to the stage in erosion reached at the present time and they are considered to be of more fundamental significance. Some of the types are highly localised or rare; dissection is by far the most important type in the Pennines and only this has been mapped consistently from the photographs.

The several types of erosion systems appear to be related to different processes of erosion and to the physical structure of the peat and bog vegetation. Erosion systems develop by the two main processes of water erosion and the mass movement of peat.

A. Water erosion. This proceeds by the development of:

1. *Dissection systems*, which progress into and within the peat mass by the action of running water. These are very common and often extensive by comparison with all the other types of erosion. They will be considered in greater detail at a later stage (Fig. 2, Sketches 1 and 2).

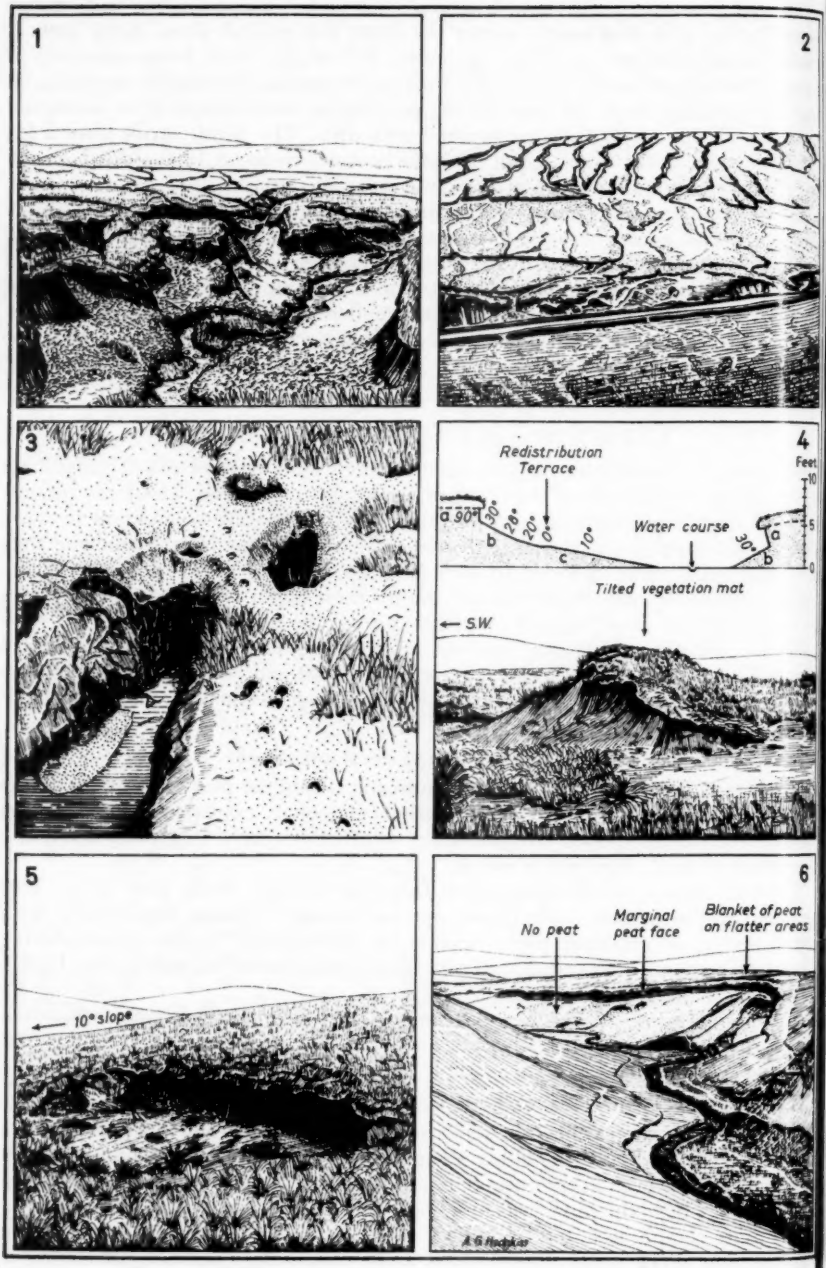
2. *Sheet erosion*, which takes place from the surface of the peat mass. This occurs if the vegetation cover breaks up, for example on some bog surfaces with cotton sedge, where mud pools develop on the surface. It also occurs during dissection on some high and climatically very exposed summits, and during Type 1 dissection if incision slows down.

3. *Marginal faces*, which often develop at the edge of the peat mass, where the peat formerly thinned to a feather edge above an abrupt increase in ground slope: the edge is eroded back to form a steeply inclined peat face (Sketch 6).

B. Mass movement. This takes place:

1. On slopes, where the peat tends to flow down-slope and the tension thus created is relieved by tearing either along or diagonally across the contour (Sketch 5). This happens even in thin peat (e.g. 2–3 ft. deep) on the steeper slopes. In deep and very wet bogs this may lead to a bog burst. In detail the cause of bursting is much more complicated, but basically it is due to the tendency for a peat bog *on* a slope to flow down it (2). Bursts appear to be rare in the Pennines but tearing is fairly common.

2. In peat overlying drift-covered limestone. In this, sink holes often develop due to the opening up of an underground drainage system in the limestone.


1
2
3
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Redistribution Terrace
Feet
10
5
0
a 30°
30°
20°
20°
0°
10°
b
c
Water course
30°
a
b
Tilted vegetation mat
S.W
5
10° slope
6
No peat
Marginal peat face
Blanket of peat on flatter areas
A.G. Hodgson

Fig. 2.

Dissection Systems in Blanket Peat

The dissection systems are of two very different types. They differ in the pattern of gullying and they affect peat of different types and depths and in different landform situations. In both cases the gullies may originate in any of three ways. In particular instances two or more of these methods may combine.

1. Within the peat mass, probably starting as lines of seepage along horizontal or vertical lines of weakness within the peat (Sketch 3).

2. As runnels on the peat surface, which will be encouraged if the surface slopes or the vegetation is burned.

3. By headward erosion of gullies from the margins of the peat mass. These follow the surface and will be guided by any lines of weakness on it.

The two types of dissection will be referred to as Types 1 and 2. They are seen in Sketches 1 and 2. In Sketch 1 deep peat on a flat area is intensively dissected by a close network of gullies, of Type 1. In Sketch 2 showing Type 2, the network of gullies is a more open one; in this case as it is taking place in peat on a slope, the pattern tends to be a linear one.

In the Pennines Type 1 dissection has been observed only in peat at least 5–7 ft. deep on slopes of less than about 5°. In the case shown in Sketch 1 the peat was about 7 ft. deep; erosion is now at an advanced stage and the peat mass has been reduced to a large number of small rounded islands. Thus there is *the rather anomalous situation of the most intensive dissection occurring on the flattest area.* On flat sites where the peat is thinner (i.e. less than 5–7 ft.) the pattern is much more open, for the gullies very rarely branch. The pattern has much in common with that on slopes and the two are grouped together in Type 2; although it should be noted that thin peat on flat areas is not usually dissected. All peats on slopes exceeding 5° show Type 2, *if* they are dissected. The accompanying map (Fig. 1) illustrates this distribution. Type 1 dissection is common on the flat central sector of the interfluve and areas with Type 2 are widespread on the valley side slopes. The areas of peat not affected by erosion are generally the thinner peats at lower altitudes, and islands of peat between dissected areas on the interfluves.

Type 1 *dissection.* The gullies advance headwards and laterally into the peat mass, and all incise to the peat base at an early stage in their history. The gully frequency is high; it is usually highest at the head of the system where many of the gullies can be seen to head in pools or depressions on the peat surface. The gullies branch

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(1) An advanced stage in Type 1 dissection of deep peat (7 ft.) on a flat area. The pattern of gullying is close and complex and many of the gullies have incised to the peat base. (Moor House Nature Reserve, Upper Teesdale.)

(2) An advanced stage in Type 2 dissection of moderately deep peat (4–5 ft.) on a 10–20° slope. Lead mining activities have interfered with the peat on the lower slope. Many of the gullies appear to pre-date mining: traces of their courses may be discerned below the contour aqueduct for mining. (Upper Weardale.)

(3) A gully starting as an underground watercourse with its floor at the peat base. It is now opening to the surface by intermittent collapse of the unsupported peat above it. (Holme Moss, Southern Pennines.)

(4) The morphology of gullies and islands developed during dissection. Faceted slopes are often developed, as illustrated in the sample section of a gully—(*a*), free face; (*b*), constant slope; (*c*), waning slope (after Wood, 1942). Angles of slope are given in degrees. Redistribution terraces are places where peat is temporarily deposited.

Many islands, particularly in Type 1 dissection, are asymmetrical in south/west/north/east section. This is attributed to more rapid erosion on faces exposed to the south-west quadrant. The tilting of the vegetation mat is attributed to erosion by water; much rain is associated with winds from the south-west quadrant and it will be driven on to the island and some will drain away down the leeward facing slope, i.e. causing erosion and lowering of the mat on that side. (Moor House Nature Reserve, Upper Teesdale.)

(5) Tearing and sliding of masses of peat is fairly common on slopes. A vertical peat face, arc-like in plan, remains. (Little Dun Fell.)

(6) A marginal peat face is produced by erosion of the feather edge of the peat blanket above an abrupt increase in ground slope. (Stainmore.)

and intersect freely and frequently, at all angles, and often regardless of the direction of slope, if there is any slope. Individual gullies have highly segmented or sinuous courses. The peat mass is thus reduced to a large number of small islands, of a height equal to the original peat depth. Later they are reduced in height as well as in area, partly by shrinkage of the peat as it dries, and partly by erosion from the surface (Sketch 4).

This is the usual sequence of events, but in a few cases of Type 1 dissection, the gullies do not incise to the peat base. After a certain point incision appears to slow down, but lateral erosion continues and extensive peat flats are produced. Sheet erosion then occurs over the whole surface. This has only been seen where the peat was originally very deep—10 ft. deep in most cases. Examples are seen on Kinderscout and in Upper Teesdale. The cause of this may often be the more resistant nature of the lower part of deep peats. In some cases there are other possible explanations.

On high, very exposed summit sites, another variation of Type 1 dissection is sometimes seen. The vegetation breaks up at an early stage and instead of the normal vegetation-capped islands, low bare peat mounds are produced. Large areas of peat are laid bare and in the worst cases adjacent gullies coalesce and it would be more correct to refer to this as sheet erosion than as gullying. Erosion probably proceeds very rapidly and tends to be very complete.

Just as stage is relevant in the study of valley development, Type 1 dissection systems can also be subdivided on the basis of the stage in development reached at the present time. During their development, evolutionary changes take place both in the general pattern and in the long and cross profiles of individual gullies. In a traverse from the head to the foot of a single Type 1 system different stages in development may be observed. At the head of the system is the earliest stage, where pools are being drained to form shallow gullies with a close and very intricate pattern. Farther down, perhaps a few yards away, the gullies will have incised farther, they are straighter and some adjacent ones coalesce; the pattern becomes bolder and simpler. At the foot of the system the gullies cut to the peat base and are very wide; eventually the islands will be wiped out completely.

The restriction in distribution of Type 1 dissection may be interpreted as follows. It occurs only on sites that once had a hummock-pool complex on the bog surface. Drainage of such pools, which can be seen at the heads of many systems, develops the complex into the early stages of a gully-island complex. Some of the pool complexes *may be* Regeneration Complexes; in other words, as the bog surface grows upwards, hummocks and pools alternate in position, the pool of one generation being colonised and filled by vegetation to become a hummock in the next. As insufficient work has been done on this and regeneration is sometimes difficult to prove, this term will be avoided. However, such pools are sometimes very numerous and they form a network of many lines of weakness on the bog surface which may be exploited by running water to form gullies. Their close and intricate pattern is thus reflected in the Type 1 systems. The distributions of the remaining hummock-pool complexes and of Type 1 systems suggest that they are confined to deep peat on flat areas. Their restriction to ill-drained flat areas has been mentioned by previous authors but not their restriction to deep peat, as far as the writer is aware. Regeneration Complexes appear to be more typical of raised bogs than blanket bogs. In some other areas where the pools occur on a sloping bog surface, they tend to be aligned at right angles to the slope; no such alignment has been observed in the Pennines.

Type 1 dissection has not been observed in less than 5–7 ft. of peat, but it sometimes occurs in deeper peat, for example 15–20 ft. on Kinderscout and some of the deeper (than 5–7 ft.) peat in the Pennines is not dissected. Many of the Type 1 systems are in peat about 5–7 ft. deep. When erosion starts the surface drains more

freely and peat accumulation virtually ceases, so that we know the depth at which erosion started. It is suggested that when a depth of 5–7 ft. is reached on slopes of less than 5°, a hummock-pool complex tends to develop. Some are drained immediately, others survive to a greater depth. The date of drainage appears to be closely related to landform, those in protected landform situations surviving longest, such as those in deep basins of limited extent, where the deepest pockets now occur.

Type 2 dissection. This often takes place more extensively than Type 1 but the network of gullies is more open. That is to say, their frequency is low, largely because individual gullies very rarely branch (Sketch 2). The islands between them are larger and more angular in aerial outline. It will be remembered that this affects all the peats on slopes and thinner peats on flats. The pattern and frequency of gullying vary with the angle of ground slope. On steep slopes the pattern is linear: on flat areas the gullies meander widely. The frequency tends to increase with slope, and also with peat depth, as dissection progresses, and it is often high on 'exposed' summit sites. As some of these relationships tend to modify one another it is difficult to explain the frequency of gullying in individual cases.

It is much easier to see and appreciate the pattern of gullying in the earlier than in the later stages of Type 2. In the late stages lateral coalescence of adjacent gullies and mass movement of blocks of peat left unsupported by the gullies, both tend to confuse the pattern.

The Morphology of Gullies and Methods of Erosion in Blanket Peat

The cross-profiles. Many of the side-walls of the gullies show faceting similar to that of hillside slopes in this country as described by Woods in 1942 (3). As similar agents of weathering and erosion are available this seems reasonable, but the very different nature of peat as compared with rocks and drift deposits might be expected to cause differences. Free faces, constant, waxing and waning slopes are often but not always seen (Sketch 4). Sometimes the facets grade into one another in convex or concave slopes; some facets may not be developed. Faceting is generally best seen in deep and very wide gullies where agents of weathering and erosion have greatest access.

The long profiles. These show evolutionary changes but their forms vary greatly, depending on the method of origin of the gully. Many profiles are stepped and tributaries often 'hang' above the main gully.

Peat faces exposed to the south-west appear to be steeper than others, and many islands are asymmetrical in cross-section (Sketch 4). This suggests more rapid erosion on the steeper faces which may be related to the predominance of winds associated with rain from this quadrant. Thus, in the last five years at Moor House in Upper Teesdale, 68 per cent of the winds on 'wet days' (i.e. days with at least 0·04 in. of rain), have been from directions within this quadrant.

Many agents are available to contribute to the weathering and erosion of peat. Some idea of their relative importance was deduced, using as evidence the few available climatic records and the results of their action. The latter include the slope facets that are developed (free faces, constant slopes, etc.), and other details of gully forms and also the detailed surface forms of bare peat faces. Many of the bare peat faces have a roughened or toothed surface. It is suggested that this is the result of differential lifting of the lighter parts of the surface peat (for example, knots of undecomposed vegetation) by frost and drying, together with differential sculpture by rain, wind and running water. There is considerable evidence of actual erosion by these agents in the form of runnelling, and of pitted and grooved forms, which may be observed on bare peat faces. Toothed surfaces are seen only in primary peat; they do not occur in redistributed peat, that is, peat which has been eroded and later deposited elsewhere.

The Date of Onset and the Rate of Erosion

Evidence about the date of onset of erosion is limited but erosion appears to have been active in some places for centuries. It may be more common now than at any time in the past. Observations made fifty years ago usually suggest a similar situation to the present. In this context the work of F. J. Lewis (4) and C. E. Moss (5) must be mentioned. Both worked in the Pennines and their descriptions of erosion, in the Northern Pennines and Peak District respectively, could be applied to the same areas at the present time. Many of the place-names, and terms usually reserved for peat erosional features are of Norse origin; 'Hagg' and 'Grain', for example, refer to gullies in peat. Such features may, therefore, have been present before the settlement of Norse colonists in the uplands of Northern England about the tenth century A.D. Many boundary trenches, walls and roads cross-cut, and therefore post-date gullies (Sketch 2), although there are a few exceptions where they pre-date them and could therefore have caused the erosion.

The rate of erosion probably varies considerably in both time and place but no actual measurements of it have been made, as far as the writer is aware. It is likely that this is the first time that erosion has taken place on the present scale during the post-glacial history of peat development. Some earlier erosion is evidenced by deposits of pebbles and silt within the peat, but these may be due to small scale, local erosion, and not to erosion of the present type or scale.

The Cause of Peat Erosion

Peat erosion appears to be common in all the upland areas in Britain, and in the north Scottish lowland blanket peats, but is rare in lowland western Ireland. The cause of the erosion is uncertain. The writer's conclusion is that it is a natural and inevitable culmination of peat accumulation in an upland or northern climate with high rainfall. An alternative end-point to accumulation would be reached if the bog surface dried out and the bog became more stable with a rather drier type of vegetation replacing the bog plants. If this were the case, some sign of natural drying out should be expected, but is not often seen; although it is very difficult to be certain about this as great changes in the vegetation of the Pennine blanket bogs have taken place, due to biotic activities (1, 2). More often the onset of erosion appears to have terminated the phase of accumulation and a natural cause of erosion is more easily visualised. However, the various forms of biotic activity, such as sheep grazing and the practices involved in modifying the vegetation for these purposes, such as burning and draining, have a drastic effect on it. These could at least encourage erosion but it is usually difficult to prove that they have caused it. Considering the Pennines as a whole, the distribution of the types of erosion and the stages reached in erosion at the present time can be understood only in relation to physical factors of climate, landform and geology; no obvious relationship with biotic activity is seen, although more work on the history of moorland land use is needed before definite conclusions can be given. However caused, peat erosion is very common and poses considerable problems in land use. For this reason alone more research is needed in order to explain and understand these problems. The conclusions presented in this paper are tentative ones, based on a general survey of a large area. They may, therefore, require modification in the light of more detailed work in the future.

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The rate of erosion probably varies considerably in both time and place but no actual measurements of it have been made, as far as the writer is aware. It is likely that this is the first time that erosion has taken place on the present scale during the post-glacial history of peat development. Some earlier erosion is evidenced by deposits of pebbles and silt within the peat, but these may be due to small scale, local erosion, and not to erosion of the present type or scale.

The Cause of Peat Erosion

Peat erosion appears to be common in all the upland areas in Britain, and in the north Scottish lowland blanket peats, but is rare in lowland western Ireland. The cause of the erosion is uncertain. The writer's conclusion is that it is a natural and inevitable culmination of peat accumulation in an upland or northern climate with high rainfall. An alternative end-point to accumulation would be reached if the bog surface dried out and the bog became more stable with a rather drier type of vegetation replacing the bog plants. If this were the case, some sign of natural drying out should be expected, but is not often seen; although it is very difficult to be certain about this as great changes in the vegetation of the Pennine blanket bogs have taken place, due to biotic activities (1, 2). More often the onset of erosion appears to have terminated the phase of accumulation and a natural cause of erosion is more easily visualised. However, the various forms of biotic activity, such as sheep grazing and the practices involved in modifying the vegetation for these purposes, such as burning and draining, have a drastic effect on it. These could at least encourage erosion but it is usually difficult to prove that they have caused it. Considering the Pennines as a whole, the distribution of the types of erosion and the stages reached in erosion at the present time can be understood only in relation to physical factors of climate, landform and geology; no obvious relationship with biotic activity is seen, although more work on the history of moorland land use is needed before definite conclusions can be given. However caused, peat erosion is very common and poses considerable problems in land use. For this reason alone more research is needed in order to explain and understand these problems. The conclusions presented in this paper are tentative ones, based on a general survey of a large area. They may, therefore, require modification in the light of more detailed work in the future.

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THE ORGANISATION OF SECONDARY EDUCATION[1]

by

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I HAVE only a limited space at my disposal: so it is fortunate that I do not need to explain in detail (as would have been necessary four or five years ago) the now well-known failings of selection at the age of 11 for different types of school.

The most telling comment I can make about it is simply this: that after fifteen years of country-wide trial, and support by the most eminent and influential authorities, the system of directing children at the age of 11 into separate types of school is assailed on all sides, and indeed (in my view) is on the point of collapse. Even the Government's recent White Paper moves to a significant extent away from the tripartite doctrine. While still maintaining that a school should not try to do everything, it declares in favour of an overlap of ability and courses among the various schools.

The fact is that the 1950s have seen a revolution in opinion—bloodless (I hope), though we certainly cannot call it a *silent* revolution—about the organisation of secondary education. Remember that it was the Labour Government of 1945–50 which established the tripartite system and issued the 1947 pamphlet, *The New Secondary Education*, which sought to justify it. Contrast that document with Labour's present policy statement *Learning to Live* and with the Government's White Paper *Secondary Education for All: A New Drive*, both published only eleven years later, and you appreciate the extent of the change which has taken place.

Look, too, at how the trickle of administrators finding their way along the Damascus road is now growing into a stream. Latter-day St. Pauls, are jumping bravely over the fence and seizing the banner of progress. These are the inevitable, and unmistakable, signs of a great reform moving into full swing. But, as in all revolutions, there are dangers amid the new enthusiasms. Where are we going? Where should we be going?

One remarkable and encouraging thing is that no one questions the interpretation of secondary education which was written into the 1944 Act: that it should be education according to age, ability, aptitude, and the length of time a pupil is likely to spend at school. The Act recognises the great variety of individual differences. The debate is not about this, but about how these different individual needs can best be met.

Let us consider the alternatives.

(1) First, we have tried, and are now rejecting, the segregation of children in different types of school according to their ability. This requires selection and direction by the local education authority by some means or other; and we are turning away from it for two reasons. One reason is that selection for such schools at the age of 11 has been proved to be premature and inaccurate. (Half the children picked for grammar schools at the age of 11 fail to get a good leaving certificate at 16. The experts themselves admit that, out of every twenty children chosen, six will be unsuitable—and moreover that they keep out another six who should have

[1] Paper delivered to Section L (Education) on September 8, 1959, at the York Meeting of the British Association.

been admitted. Later transfer has not worked well in practice. Only one in three of those wrongly placed in modern schools moves to the grammar school; only one in twelve the other way.)

The second reason is that even if selection *could* be made accurately, the effect of competitive pressure on junior schools and junior children, of the stigma of failure on modern schools and modern school children, would be too harmful.

I could quote many individual cases to illustrate these points. The classic indictment of premature selection, however, is our best-known late developer, Sir Winston Churchill, who was always in the bottom class at school. Indeed, if the present system of selection had applied to him in the year 1888 or thereabouts, he would probably never have got in at all. This is his own description of the entrance examination that he took at Harrow (it was the Latin paper, which in the nineteenth century enjoyed much the same status as intelligence tests in the twentieth century):

> I wrote my name at the top of the page. I wrote down the number of the question, '1'. After much reflection I put a bracket round it. But thereafter I could not think of anything connected with it that was either relevant or true. Incidentally there arrived from nowhere in particular a blot and several smudges. I gazed for two whole hours at this sad spectacle: and then merciful ushers collected my piece of foolscap with all the others and carried it up to the Headmaster's table. It was from these slender indications of scholarship that Mr. Welldon drew the conclusion that I was worthy to pass into Harrow.

(2) Instead of selection *for* different types of school, however (i.e. selection *of children by experts*), we could have selection *of* different types of school (i.e. selection *of schools by parents*). I commend it to the Conservatives as a popular and widely acceptable alternative to Labour policy.

This substitution of a two-letter preposition for a three-letter one would nevertheless change the whole picture. It would end *popular* opposition to '11-plus', which comes mainly from anxious or disappointed middle-class parents. Yet it would cause the least possible disturbance to existing schools, which (except in rural districts, where the only school must be comprehensive) still would not profess to cater for everything, though they would have to teach children with a wider range of ability—as did the fee-charging grammar schools before the war.

The comprehensive school can be fitted into such a picture alongside grammar, technical and modern schools. At West Bromwich parents of 11-year-olds in one district are asked to choose between selective and non-selective education. If they prefer the former, the children take the '11-plus' and are allocated to a grammar, a technical or a modern school; if the latter, they do not take the '11-plus', but go straight to the local comprehensive school. In fact 90 per cent of the parents choose the comprehensive school. The remaining places are filled by children of parents outside the district who, before the '11-plus' was held, expressed a preference for comprehensive education.

A modified version of this 'parents' choice' principle is being introduced this year at Cleckheaton, in the West Riding. Children are allocated to grammar or modern school, on the recommendation of primary school heads. But opportunity does not stop there. The parents are being asked to say whether they want their children to follow a long-term course (11–18), a medium-term course (11–16) or a short-term course (11–15); and, regardless of the school in which they are placed, the parents' wishes will be met by means of overlapping courses. The children will continue on the course chosen for them until they prove to the satisfaction of the teachers, and (it is hoped) of themselves and their parents, that they can or cannot profit by it. In this first year of the scheme 34 per cent have chosen a long-term, 26 per cent a medium-term, and 40 per cent a short-term course. So six parents out of ten have declared their intention to keep their children at school at least until the age of 16. Teachers and psychologists help parents to choose wisely, and

later transfer will be possible. The great virtue of the plan is, indeed, this prospect of involving parents with schools much more closely than the English have yet succeeded in doing.

The Cleckheaton scheme seeks to use both expert guidance and parents' wishes and to reconcile them. Outside a comprehensive organisation it is the best attempt so far at implementing the intentions of the 1944 Act in a balanced way, and making section 76—so neglected, so important—a reality. Section 76 says: 'So far as is compatible with the provision of efficient instruction and training and the avoidance of unreasonable public expenditure, pupils are to be educated in accordance with the wishes of their parents.' The neglect of this section hitherto has meant a fundamental difference between England and North America, where parents have the final say in what courses their children take. The trouble is that the English headmaster loves to be king of the castle. In the late seventeenth century the headmaster of Westminster, a certain Dr. Busby, refused to remove his hat when King Charles II visited the school, lest his pupils should suspect that there was any man greater than himself. And that tradition has persisted.

There is one big drawback to the Cleckheaton scheme, and it turns—as does the whole problem of secondary school organisation—on the sixth form. If you are to muster in one school enough pupils aged 16–19 for a good range of sixth form courses you have at some point to put all the long-term pupils in the grammar school, and all the short-term pupils in the modern school. The latter will still be regarded as inferior.

On the other hand, if you allow every secondary school to run long-term courses you will have many small sixth forms in many small secondary schools; and the small sixth form is not only uneconomical but also *educationally* inefficient. We cannot justify classes of one or two pupils aged 16, when we have younger classes of forty and fifty. Moreover sixth form pupils need the exchange, the cross-fertilisation of ideas which you get in a class of eight to twelve students—to my mind the optimum size. Again, while I agree that we need a common core of certain studies for all sixth form pupils, individual needs are so diverse that we must offer a very wide range of options too: probably between twenty and thirty, from which each pupil will choose two, three or four. The student must not be limited by what the school can lay on, which all too often amounts to no more than a dozen subjects.

Dr. Richard Lynn, of Exeter University, has recently been studying the detailed figures for open scholarships at Oxford and Cambridge, and for the Advanced and Ordinary levels of the General Certificate of Education. He has related these to the number of sixth form pupils in the schools concerned, and worked out the proportion of successes accordingly.

His findings, reported in the *British Journal of Sociology* (June 1959), show clearly that, whereas the size of the upper school does not matter very much at Ordinary level, at Advanced level the schools with larger sixth forms do distinctly better *per pupil* than schools with smaller sixth forms. In open scholarships to Oxford and Cambridge this tendency is even more pronounced. Dr. Lynn's conclusions seem to be confirmed by the latest list of schools winning Oxford and Cambridge open scholarships last year. All the schools with four or more awards, with the possible exception of Glasgow Academy, had a sixth form of over 100, and the three leaders were Manchester Grammar School (490 in the sixth), Winchester (332), and Dulwich (250).

Here is factual evidence which bears on my main criticism of the third alternative, the orthodox comprehensive school taking pupils from 11 to 18 years of age.

(3) The big drawback of these comprehensive schools is that, unless they have at least 1,500 pupils, they cannot provide what I regard as an adequate range of

advanced courses at sixth form level. Although more children stay on longer in comprehensive schools than under the tripartite system—up to twice as many in each age-group over 15—you still need a school of between 1,500 and 2,000 (according to the locality) to be sure of 100 sixth form pupils. These 100 are, of course, divided into many different classes according to their age and special subjects.

Big schools try to get over the problem of size by sub-dividing in one of two main ways: either vertically into Houses, which are in turn based on tutorial groups of perhaps twenty-five pupils, or horizontally into lower, middle and upper schools, or even year groups. But I am not entirely satisfied that such a large concourse of people, however organised, can develop the sense of intimacy, of being not only a community but part of the neighbourhood community, which helps a boy or girl to grow roots. Nevertheless such reservations do not mean that big comprehensives are not a vast improvement on the tripartite system.

In those schools which have been developed from grammar into comprehensive, examination results have certainly improved; and about twice as many pupils as the national average are staying to take the Advanced level of G.C.E.

But there are more important things about a school than its examination results. Dr. Trevor Miller, an Australian research worker at the education department of Birmingham University, recently made a careful, objective study of children's attitudes in different types of school.

Dr. Miller took three different areas of the country, and in each area he matched a group of grammar school boys (GS) aged 13–14 with boys of similar age, intelligence and social background in a local comprehensive school (CG). He did the same with modern school boys (MS) and similar boys in the comprehensive school (CM). He prepared and gave them suitable tests; and this is what he found:

(*a*) The CG boys had a very slightly higher proportion of active leisure-time interests (e.g. playing rather than watching football) than the GS boys: third came CM, a bad last MS.

(*b*) The group which had the highest opinion of its own school was CM; second came CG, third GS, fourth MS. At the same time the boys' estimate of their school's standing in the eyes of the public was realistic: (1) GS, (2) CS, (3) MS.

(*c*) CG and CM together had the highest opinion of their school's *courses*; GS and MS came lower, and close together.

(*d*) Tests of 'morale' and attitude to schooling and education generally (e.g. homework) produced this order: (1) CG, closely followed by (2) GS; (3) CM; (4) MS.

(*e*) Finally, all the boys were asked: 'Do you wish to leave school as soon as possible?' The answer 'No' came as follows: CG 93 per cent; GS 83 per cent; CM 72 per cent; MS 57 per cent.

Perhaps the most significant feature of these figures is that even in the modern schools, where pupils clearly felt themselves and the school to be inferior, more than half wanted to continue their education. It ties up with the figures already quoted from Cleckheaton (and others to which I shall refer later), suggesting that there is an enormous, unsatisfied demand for higher secondary education; a significant reserve of talent thirsting for full nourishment and training. So far we have scarcely begun the process of giving secondary education to all who can profit by it: and this goes for university education too. This is very significant for us here in York, where we are all hoping that a university will soon be established.

Social surveys are always open to criticism, and one would not wish to press Dr. Miller's detailed findings too far. They do, however, indicate quite clearly that, far from the attitudes of 'grammar' type pupils in comprehensive schools being

adversely affected, they are at least as good as those of similar boys in separate grammar schools. Likewise, in every respect the comprehensive school is beneficial to 'modern' type pupils.

The contrast between the theories of some critics and Dr. Miller's entirely objective observations reminds me of a conversation which once took place over dinner in an Oxford College. Dr. Jowett—a famous figure at Oxford—was arguing that the State was more important than the Church. His opponent said No: 'A judge can only say to a man, "You be hanged," but a bishop can say to a man, "You be damned."' 'Ah, yes,' said Jowett: 'But when a judge says to a man, "You be hanged," he *is* hanged.'

So the main objection to orthodox, 11–18 age-group comprehensive schools turns not on the insubstantial bogies of loss of values, lower standards, and so on, but on the practical issues of size and sixth form. To be efficient at the sixth form stage they must be bigger than most of us like; and because of this need for size, they cannot be generally provided for many years to come. Yet the need for reform is urgent.

(4) My own answer to this problem is what I call 'two-tier' secondary education. It is a system common in North America, and some of us have been advocating it in England since 1944. A survey which I made of local secondary schools in 1948 pointed in this direction. But in those days to organise secondary education in two stages would have meant that most grammar schools lost their sixth forms—the solution which Croydon came near to adopting in 1954.

By then, however, the increased number of pupils staying beyond the age of 15 in fact made it unnecessary to behead the grammar schools in order to get the advantages of the two-tier system: all the grammar schools with more than 300 pupils—that is, the vast majority—would themselves be needed for the higher education of older boys and girls only. In 1955 I found the Midland branch of the Association of Education Officers keenly interested in this new evidence and in the idea which naturally went with it: to abolish '11-plus' selection, put modern and grammar schools end-on, and develop them as junior and senior high schools respectively. In the following year I had the privilege of discussing this plan more fully with the Minister of Education and some of his advisers—including the proposal that, as an interim step, optional transfer from the modern or junior high school to the grammar school should be made at the age of 14 by those children whose parents promised to keep them at school at least until 16.

Several local authorities showed a lively interest in this new approach, but they were understandably reluctant to embark on such a change just when the population bulge was about to hit the secondary schools. Despite this difficulty, however, in 1957 Leicestershire introduced essentially the same plan, except that 'flyers' (the top 10 per cent) were to be withdrawn from junior schools at the age of 10 and taken through the junior high and grammar schools a year in advance of their fellows so that they would be able to enter the sixth form at 15.

Various versions of two-tier organisation are now being considered, or have been adopted, by different local education authorities. Stoke-on-Trent are debating the pros and cons of a general break at the age of 13 as against one at 16. Rotherham has proposed that 'flyers' should move at the age of fourteen, others at 15. Both these authorities have sought full and frank discussion by teachers and the public before any decision is taken: a lesson which might be learned elsewhere.

Carlisle is following Leicestershire. The West Riding and Derbyshire are both prepared to consider a two-tier solution in some areas. At least one divisional executive in Middlesex favours it, but has had to bow to the big guns of orthodox Labour (which there favours the normal comprehensive school) on the county council.

The two-tier movement is spreading. It seems, indeed, the only way in which, under the present Education Act and without years of delay, we can gain the advantages of comprehensive education without the disadvantages of either the outsize school on the one hand or small and inefficient sixth forms on the other.

It has, moreover, advantages peculiarly its own. Not least among these is that it can be introduced without reference to the Minister of Education at all, provided the opening, closure, or substantial enlargement of a school is not involved.

Again, it enables schools to retain the intimacy and compactness which should go with moderate size. The grammar schools are freed to develop their own special contribution to English education, the sixth form, to a degree hitherto undreamed of; and they should be able to compete on equal terms, as few maintained grammar schools can yet do, with the leading public schools. Socially they can—if they will—become more mature communities than is normally possible in schools made bottom-heavy by large numbers of younger children.

We should not be put off by certain contradictions in the Leicestershire version which were, I think, at first necessary to secure the co-operation of the grammar schools, but which could now be reconsidered. The transfer of 'flyers' from primary to secondary schools below the age of 10 years 6 months is in fact illegal, though the Ministry has so far taken no steps to prevent it. Again, there may be some conflict between an avowed dislike of segregation at the age of 11 and the earlier selection, within the primary school, of an élite; and, as Professor Vernon has pointed out, the latter must be even less accurate than the former. It is not very wise, for the sake of the children themselves, to start picking your sixth form scholarship hunters at the age of 9.

It may be, too, that the undertaking required of parents whose children transfer to the grammar school (though it cannot be legally enforced) is in some cases a deterrent to extended schooling. Last year only 33 per cent of all the 14-year-olds in industrial Hinckley, and 42 per cent in suburban Wigston, were in the grammar school and therefore staying to the age of 16. Though the position has improved this year to around 40 per cent and 50 per cent respectively, the figures still compare unfavourably with over 60 per cent who stay to the age of 16 at some Birmingham modern schools which offer advanced courses, and over 80 per cent at Woodberry Down comprehensive school, in London.

During a visit to Canada, earlier this year, I made a point of looking closely at their experience of junior and senior high schools, which they have had for over thirty years. South Peel, in Ontario, has optional transfer after three years in 'junior high'—an arrangement closely similar to that now begun in Leicestershire. Both authorities find that it is mainly the cleverer pupils who go on to the senior high or grammar school.

On the other hand North York, a rapidly growing town of 250,000 people near Toronto, where the leaving age is 16, finds it better to transfer all pupils at 15 to the splendidly equipped senior high schools, well furnished for all kinds of practical and technical as well as academic work. Teachers and officials think it particularly important that the less able pupils (who are, however, physically and socially mature) should advance with their contemporaries rather than stay behind at junior high school to dominate younger children. Quite often this promotion leads boys and girls to stay at school till the age of 17 or 18, who otherwise would never have done so. Here, it seemed to me, was a model for us when our minimum leaving age is raised to 16 and when the effective leaving examination shifts (as it must do with more and more pupils staying longer at school) to 18.

(5) So far I have spoken of secondary education as it is at present defined—a separate stage covering roughly the age range 11 to 18. But we may ask why, if we are to drop selection at the age of 11, there should be a break of any kind at 11.

The independent system commonly has kindergarten to the age of 9, preparatory school 9–13, public school 13–18. It is a reasonable objection to the two-tier secondary system that it will often mean that a child must move through no fewer than four schools in all: infant, junior, junior high and senior high.

The Ministry of Education already allows many local authorities to transfer some children from primary to secondary school below the legal minimum age: then why not 50 per cent, or even all children? Legally no distinction can be made between clever and average children in this matter. What's sauce for the goose is sauce for the gander! I am waiting for some enterprising L.E.A. to announce its plans for a system of comprehensive education in three stages rather than two or four: say, 5–10; 10–13; and 13–15 . . . 18. It is difficult to see on what grounds the Minister could now intervene to forbid such a development, even if he wished to do so—and there is of course no reason to suppose that he would so wish.

In such middle schools (10–13) a gradual transition from class teacher to subject specialist could take place. The general study of science and a foreign language from the age of 9 or 10 onwards would be facilitated.

At the same time the high school would be able to cover the whole period of adolescent flowering, the period of gradual, individual differentiation from the age of 13 onwards to 18, without awkward breaks and attempts (not always successful) to get the staffs of junior and senior high schools to agree on the dovetailing of G.C.E. work in their different schools. And if the system were introduced tomorrow, it would still ensure that every child had at the very least a year and a term in which to savour the opportunities offered by the high school, with the likelihood that many would choose to stay longer.

These high schools could be comparatively small. According to the locality, 800–1,200 pupils, aged 13–18, would include a sixth form of over 100, and make the provision of a very wide range of advanced options possible. I found such high schools, with this age range, working well in the Protestant schools of Montreal, where Scottish tradition and American influence combine to ensure a happy balance of academic and technical studies in democratic communities. We have many schools—grammar, technical, modern, comprehensive—which are ripe for development into schools of this type and size. Their individual character would not, I think, be lost.

Summing up, then, there are four main alternatives to the present system:

(1) selection of different types of school by parents;
(2) the large comprehensive secondary school, 11–18;
(3) comprehensive secondary education in two stages, with a break at 13, 14, 15 or 16 (the age might vary in different localities or with individual pupils);
(4) comprehensive schooling in three stages, not two or four: i.e. (say) 3 . . . 5–10; 10–13; 13–15 . . . 18.

Which do you prefer?

I have said my say about organisation. But before I end I must make one comment. All these reforms in the framework of the system can do no more than make good education possible. They simply get us to the starting gate. What really matters is what happens *inside* the schools. And this depends on the teachers. But that, as the children's adventure books say, is another story.

THE MECHANISM OF INHERITANCE[1]

by

P. M. A. BRODA

CLASSICAL geneticists, particularly of Morgan's school, showed that the large majority of factors for observable characters (termed 'genes') are borne on the chromosomes in the cell nucleus. The measurement of linkage and crossing-over values has been used to construct 'chromosome maps' in which each gene is assigned to a definite position on a definite chromosome. The arrangement of genes on chromosomes is analogous to that of beads on a string.[2]

That there is a definite and direct causal relationship between the presence of a gene and the appearance of a character has been shown several times as regards the chemical process taking place, for instance by Tatum and Beadle with the fungus Neurospora (2). Further, a correlation has been found between the quantity of a substance produced and the number of times the corresponding gene is present. For instance, more is found if the organism is polyploid than if it is diploid, or again if it is homozygous instead of heterozygous for that gene.

It was only about 1930 that people started working on the chemical basis of inheritance, and only since the war that nucleoprotein, and, more particularly, desoxyribonucleic acid (DNA) has been established as the carrier of heritable 'information'. The evidence is sparse, yet it is overwhelming. The line of argument may be presented thus: metabolic processes can eventually be traced to enzymes, which must themselves be synthesised, but cannot duplicate themselves. The proteins of an organism are specific and this specificity is heritable; heredity is carried on the chromosomes, in which DNA is always present. DNA is in general not found elsewhere in the cell.

Griffith (3) showed in 1928 that when a mouse was inoculated with a mixture of living pneumococci of one type and dead pneumococci of a second and quite different type, there would arise in the mouse living pneumococci of the second type. This phenomenon is called transformation and is now known to be caused by the (purely chemical) basis of inheritance of the second strain being incorporated into the heritable make-up of the first. Avery and his colleagues (4) have since shown that this transforming agent is DNA. This conclusion has been verified many times in similar experiments.

Normally DNA is chemically combined with basic proteins as nucleoprotein. Hershey (5) has shown with 'T2' bacteriophage that DNA penetrates the bacterial host and that almost all the protein is left behind. It does not seem that protein is a carrier of genetic information.

More will be said on this subject later, but it might be noted here that from the structural point of view DNA is better equipped with the necessary attributes for synthesis and replication than any other known high polymer.

In Tobacco Mosaic Virus (TMV) it has been found that DNA is absent and ribonucleic acid (RNA) appears to carry at least part of the information which determines the composition of viral protein. In a series of beautiful experiments Fraenkel-Conrat (6) and, simultaneously, Gierer and Schramm (7) divested TMV of its normal protein coat and gave it a different one. This 'hybrid' was inoculated

[1] First prize essay in the 1959 Endeavour Essay Competition. Mr. Broda is a student at King's College, Cambridge.

[2] In this essay I have assumed that apart from plastids, mitochondria and 'plasmagenes', the material of heredity in cellular organisms is situated in the nucleus alone. This view has been challenged by Professor H. Graham Cannon in his recent book, *The Evolution of Living Things*. (1)

into tobacco plants, and the viral progeny examined. It was found that the RNA was identical with that inoculated, and that the protein was of the kind normally associated with that RNA.

The conclusions of biologists concerning the chemical basis of heredity have been reinforced by mathematicians and physicists. Turing and later Von Neumann (8) claim to have shown that a system which can both produce and reproduce can be made out of a reasonably small number of components, and that a vital force need not be postulated. Schroedinger (9) has suggested that from the point of view of quantum mechanics the system must be unimolecular.

It has been found that DNA is composed of nucleotides each consisting of a molecule of desoxyribose (a pentose sugar) a phosphate, and a nitrogenous base. In DNA four bases are found, two purines (guanine and thymine) and two pyrimidines (adenine and cytosine). Each nucleotide contains only one of these (Fig. 1).

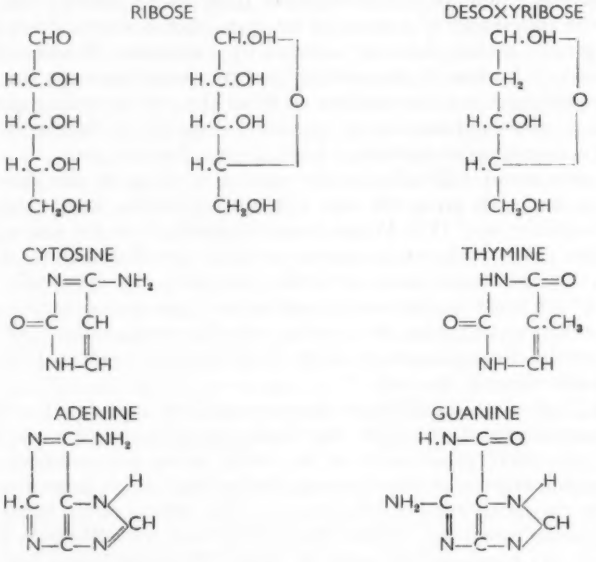


Fig. 1.—Some constituents of nucleic acids.

A major advance was made in 1953 by Watson and Crick (10), who, using X-ray crystallographic results, put forward the now generally accepted model for the structure of DNA. According to them, there are a pair of threads twisted round each other in a double helix, a constant distance apart. Each thread is made up of alternate phosphate and sugar groups, with the base attached to the sugar; the link between the chains is relatively weak, a hydrogen bond between complementary bases; each base has a definite partner, which is invariable. The possible base pairs are cytosine-guanine and adenine-thymine. Thus, given the sequence of bases on one of the threads, the sequence on the other is automatically fixed. A normal gene may have ten to fifteen thousand base-pairs. In different genes the proportions of different base-pairs vary; it is assumed that the order of bases determines the specific properties of a gene (Figs. 2, 3).

Since the publication of this work tremendous advances have been made in developing theories on the specificity of DNA, its replication, enzyme production and mutation. Beadle (11) states that the number of possible forms of DNA far

exceeds the number required to give each gene found in living matter a different constitution. This is of course necessary to the concept that different genes are DNA molecules with different sequences of base pairs.

Duplication of DNA appears to be a template mechanism of the 'hand and glove' type. The original pair part along the line of weakness given by the hydrogen bond and each of the threads forms a complementary partner. In this way four strands are formed from the original pair. This can easily be visualised in the

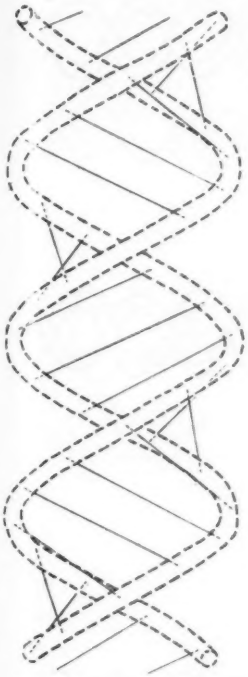
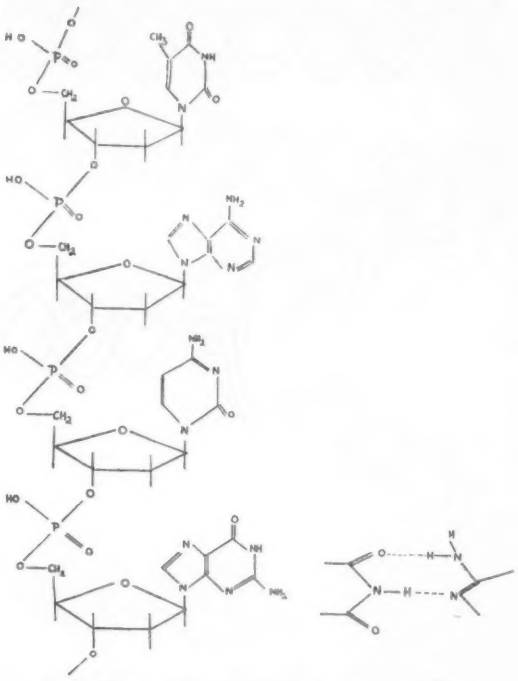


Fig. 2.—The Watson-Crick model for the structure of DNA. The two helices are linked by black lines which represent the base-pairs.



(*a*) (*b*)

Fig. 3.—(*a*) The spatial relationship of desoxyribose, bases and phosphate groups in DNA. (*b*) Possible method of hydrogen bonding between complementary base pairs.

Watson-Crick model (Fig. 4). It would seem reasonable to suppose that each strand remains intact during replication; the fact that DNA is relatively unreactive is additional evidence for a template mechanism. Also, the number of 'mistakes' in replication is only in the order of one in a million, an unlikely value if the molecule had to be broken up and reassembled at each duplication.

One field in which there now seems considerable uncertainty is that concerning the precise mechanism of chromosome division, since contradictory evidence has been presented by different scientists.

Taylor (12) labelled chromosomes with tritium-containing thymine to find how the radioactivity was distributed among the daughter chromatids. He found that after the first division it was divided equally among them, but that in the second division half were non-radioactive and the other half were labelled. This suggested that at the time of labelling the chromosomes were already double structures, which then divided; the daughter chromosomes on division each produced one radioactive and one normal chromatid. This implied that the radioactive one

remained intact and was a template for the formation of a non-radioactive partner (Fig. 4).

It is tempting to suppose that the chromatids are simply chains of DNA. But if this was so, the chains would have to be more than a yard long and twist round each other 300,000,000 times. Freese of Harvard has suggested a model which would be consistent with the linear order of the genes on the chromosomes, the

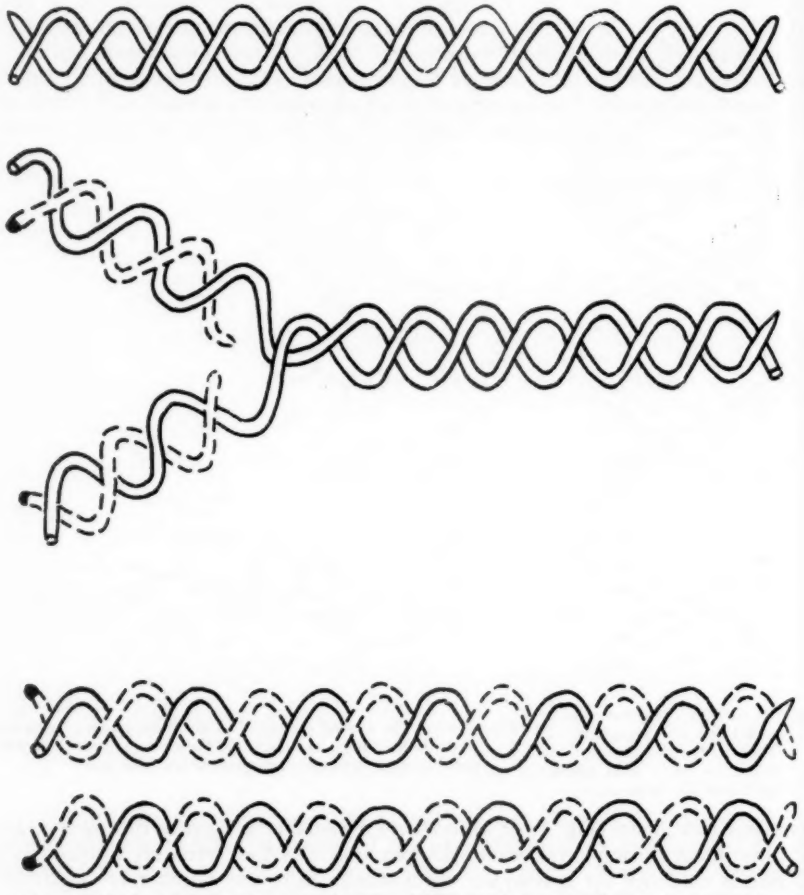


Fig. 4.—Taylor's theory of gene replication. When the helices duplicate, they unwind and each builds itself a new partner. One cycle is shown; it takes place in radioactive solution, producing two labelled chains. When a labelled molecule duplicates itself again in non-radioactive solution, only one of its descendants contains a radioactive chain.
Broken line=Radioactive; Continuous line=Normal.

intimate connection of protein with DNA, and Taylor's results. He visualises two parallel protein spines with DNA running to and fro between them like the rungs of a ladder. The protein blocks of each thread are joined by calcium bonds, giving considerable flexibility and allowing the chromatid to fold and coil on itself as it does when observed microscopically (Fig. 5). Replication takes place by the unwinding of complementary DNA strands; each then forms a new partner and second series of protein blocks. One way in which this theory might be tested

would be to 'label' the protein strands and see whether they segregate into normal and radioactive daughter chromatids.

La Cour and Pelc (13) have since published results which apparently directly contradict Taylor's work, since in their experiments the chromatids produced in the second division were equally radioactive. If this is in fact so, a drastic revision of present theory would be necessary, but other work supports Taylor's main conclusions.

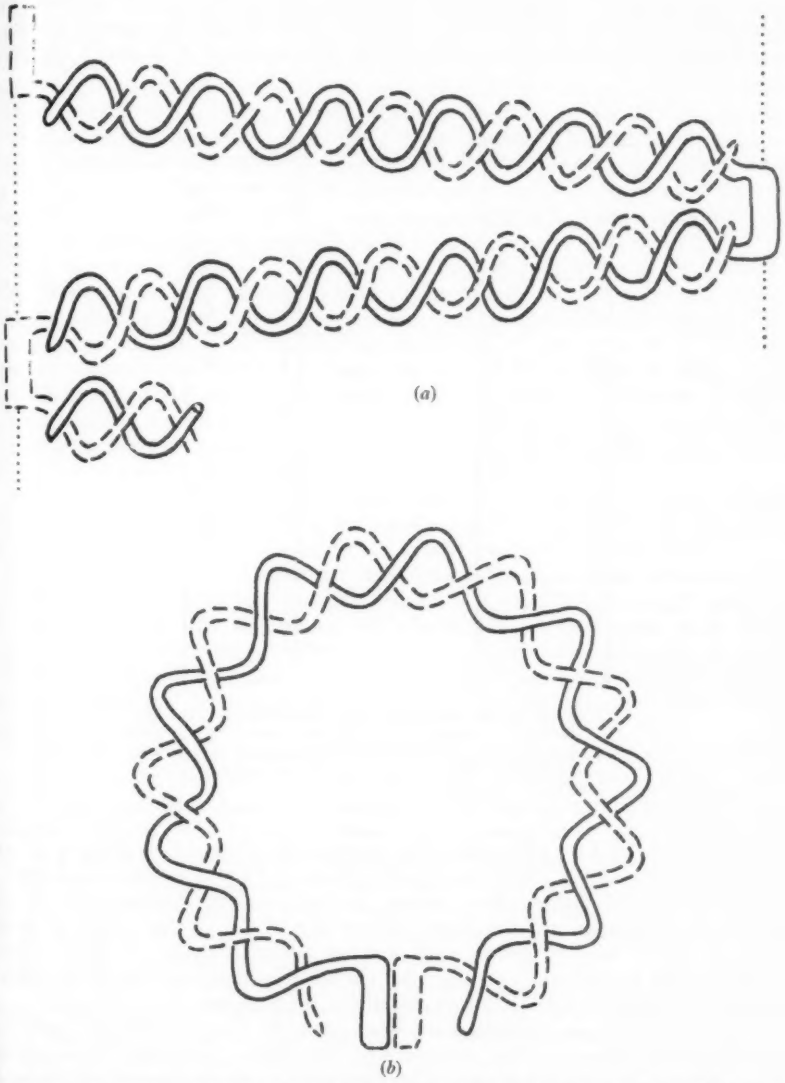


Fig. 5.—Freese's model (after Taylor). (*a*) One chain of each molecule is attached to the right-hand column, the other to the left-hand one. The rectangles represent structural material of the columns; dotted lines indicate bonds which may include calcium. (*b*) When the chromatids become visible, the columns come together. View end on.

Any theory on protein synthesis must explain how the 'blueprint' for protein specificity is contained in the DNA while the actual site of protein synthesis is in the cytoplasm. DNA is never found there, with the minor exception of κ-particles in *Paramecium aurelia*. Brachet postulates that RNA is an intermediate which is produced to a specific form by DNA and in turn makes a corresponding protein; this would imply that for each variety of DNA there is a corresponding type of RNA. Evidence in favour of this view is the presence of RNA in the cytoplasm and the correlation first pointed out by Brachet (14) and by Caspersson *et al.* (15) between the quantities of RNA present and protein produced. In contrast, the weight of DNA present in the diploid or haploid nuclei of cells of a species is always constant, apart from differences explicable by the possession of X and Y chromosomes.

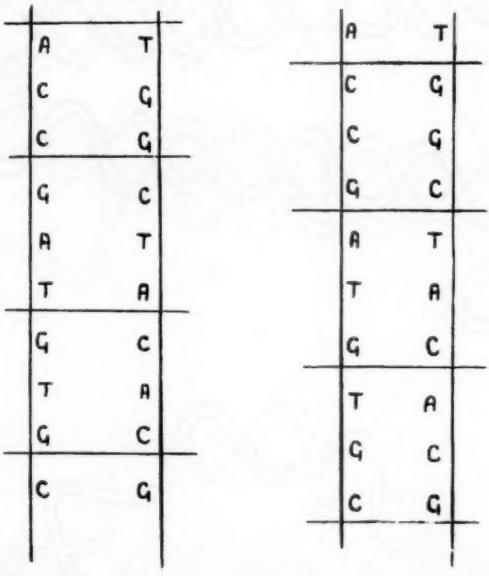


Fig. 6.—Sense and nonsense. The triplets on the left are arbitrarily defined as 'in the dictionary'. When the same sequence of base-pairs is divided up differently, no sensible triplets occur, that is, the sequence makes complete 'nonsense'.

This theory provides a plausible explanation for the apparent carrying of genetic information by RNA in TMV; the RNA induces a particular host DNA-type to produce viral RNA, which then makes its characteristic protein coat. It also suggests an explanation for the extraordinary size of the chromosomes in *Drosophila melanogaster* salivary glands; each of these appear to consist of about a thousand chromatids lying together in parallel. Could it be that here the RNA stage is completely by-passed and DNA acts directly as the template for synthesis?

In the last four years attempts have been made by Gamow (16) and others to relate protein synthesis to the structure of the DNA. Assuming for simplicity that the integration of each amino-acid is related to a particular nucleotide sequence, it appears that the ratio of nucleotides to amino-acids is in the order of ten to one. This value is called to 'coding ratio'. However, it is by no means certain that the initial assumption is correct, or that all nucleotides take part in synthesis. The

'value' of this ratio, if it exists at all, is in giving an idea of what sort of number of nucleotides may be concerned in the integration of each amino-acid. Various such coding hypotheses have been developed; there are four possible base pairs—thymine-adenine, adenine-thymine, guanine-cytosine and cytosine-guanine. If a single base-pair determined the incorporation of an amino-acid, only $1 \times 4 = 4$ different ones could be utilised. A pair could distinguish between $4 \times 4 = 16$, which is still not enough, and a triplet between $4^3 = 64$, which is too many. The next step is to cut this down to exactly twenty. All possible permutations are arbitrarily assigned into one of two categories 'sense' and 'nonsense', so that when 'sense' permutations are placed in a linear sequence (as in DNA) it is quite obvious where one ends and the next begins. If attempts are made to make triplets starting from the wrong point, only 'nonsensical' triplets will be obtained (Fig. 6). Crick, Griffith and Orgel (17) have produced such systems in which the maximum number of groups 'in the dictionary' is twenty. They emphasise that there is no experimental evidence to back these hypotheses and recognise that they may themselves be producing nonsense. One drawback of this particular hypothesis is that the same sequence is used in both directions, each corresponding to a different amino-acid. If they are used just in one direction, only ten types can be obtained.

Such hypotheses suggest a connection between the structure of the individual DNA molecule and the protein to which it eventually gives rise. Such a relationship undoubtedly exists, but it must be borne in mind that it is indirect, since RNA is an intermediate. For this reason, the elucidation of the structure of RNA is of great importance. Its chemical constituents are similar to those of DNA, except that ribose and uracil are present instead of desoxyribose and thymine. It appears to have a helical structure, but in TMV it exists as a single chain. A structure fairly similar to that of DNA can reasonably be postulated, but X-ray diffraction methods have so far not yielded conclusive results.

An interesting question is how the incorporation of other amino-acids occasionally encountered in protein can be explained in terms of coding theory. Speculation here can run to even greater lengths than with the twenty principal ones.

It has been shown that mutations may cause changes in the structure of the protein produced. Sickle-cell anemia, which is inherited as a single gene in a Mendelian fashion has been shown by Ingram (18) to be caused solely by the incorporation into haemoglobin, which has about three hundred amino-acids, of a molecule of valine in the place of the glutamic acid found in normal haemoglobin and lysine present in haemoglobin C. This is readily explicable in terms of coding hypotheses (Fig. 7).

Beadle (19), accepting some type of coding mechanism as a working basis, lists four possible ways in which DNA may be altered, each capable of causing a mutation. These are rearrangement, substitution, duplication and deletion of one or more base-pairs (Fig. 8). Using the Watson-Crick model, it can readily be seen that base-pair order can be of great importance; Benzer (20) has in fact shown that mutations in bacteriophage may in some cases be caused by changes in not more than two adjacent nucleotides (such a unit is termed a 'muton') and it is quite on the cards that a muton may often be a single base-pair. It does not seem that changes in the associated protein cause mutation.

Since the order of nucleotides on the double helix seems so important, it would appear that the whole DNA molecule should be present for proper functioning. Yet it was reported late in 1958 that Allfrey and Mirsky had removed up to 75 per cent of a DNA molecule and replaced it by a negatively charged foreign polyelectrolyte, polyethylene sulphonate (21). They found that the functioning of the DNA was unimpaired, provided the electric charge on the substituent was negative. If this is true, it could mean that a 'gene' may in fact be a string of functional units, 'cistrons' in Benzer's terminology.

Until now only the role in heredity of the nucleus has been considered. Cytoplasmic inheritance has been reported in a number of widely different species of organism, and the use of such terms as 'plasmagene' has been applied to such factors. Some, such as κ-particles in *Paramecium aurelia*, resemble viruses, but the

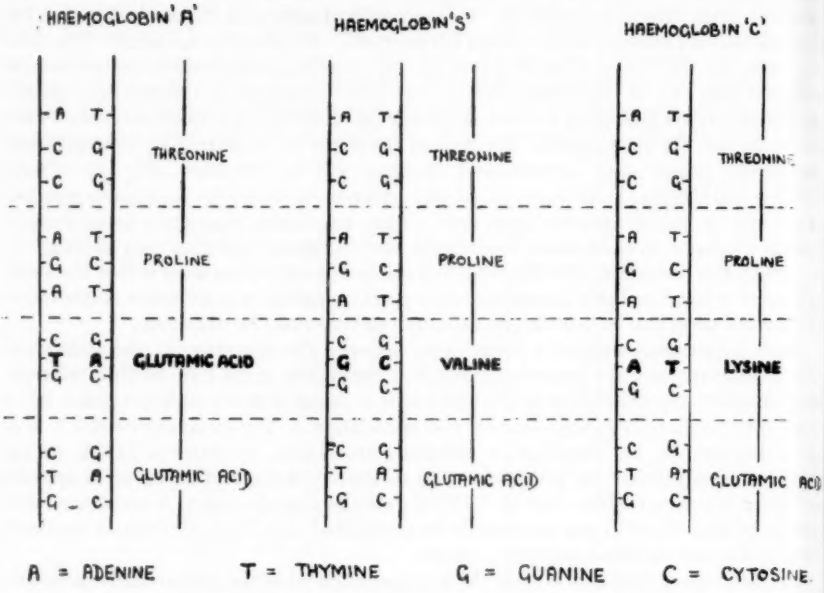


Fig. 7.—A hypothetical relationship between sequences of base-pairs and of amino acids (after Ingram).

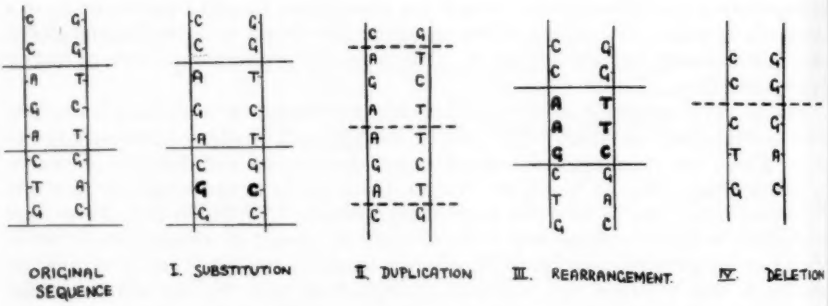


Fig. 8.—Beadle's four types of mutation in terms of coding hypothesis.

replication of for instance plastids and mitochondria may be of real interest and relevance; very little is known at present.

In a field as new as this many questions arise even in matters affecting the fundamentals of the subject. The remarkable uniformity of DNA throughout living matter has not so far been explained; maybe the type which exists today is the only possible one; it is more likely that originally there was a variety of widely

different replicating macromolecules of which DNA is the survivor. Allfrey and Mirsky's work is a start in the quest to find how small a functional gene can be.

Workers in this field expect great advances in the next decade, for instance an elucidation of the structure and importance of RNA, and its relationship with DNA and with protein. It will then be possible to retain or reject the current theory that RNA is the active and to some extent expendable unit of the system of which DNA is the safe and permanent blueprint. Another question is why DNA can replicate while RNA apparently cannot.

There is much in this field in common with the study of the origin of life, particularly ideas concerning the 'primitive gene' and whether RNA, DNA or some third nucleic acid was the earliest. The implications for the whole of science are of the greatest importance, for here is an attempt to explain the basic mechanism of life in terms of atoms, molecules and models in the same way as non-living systems have been explained in the past.

ACKNOWLEDGEMENTS

The writer would like to thank Dr. F. H. C. Crick, F.R.S., for his kindness in discussing with him some of the recent developments in this field.

Illustrations; Fig. 2, *Nature*, 1953; Figs. 4 and 5, *Sci. American*, June, 1958.

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THE ADVANCEMENT OF SCIENCE

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE was founded in York in 1831. The popularising of science was one of its main original objectives: it still is but the audience is now different. Then it was a small educated minority, now—directly or indirectly—it is the whole nation. While, therefore, the Association's Annual Meetings still provide an unique opportunity for scientists, as well as for non-scientists, to meet together, the Association is also now engaged in a major effort to present science to the public at large throughout the year.

The Council of the Association have decided, therefore, to make a number of changes in their journal, THE ADVANCEMENT OF SCIENCE, as part of this expanded campaign of new activities.

From May, 1960, THE ADVANCEMENT OF SCIENCE—at present a quarterly magazine—will be published six times a year in an entirely new format.

THE ADVANCEMENT OF SCIENCE will contain articles contributed by eminent scientists at the Meetings of the Association, especially invited articles, notes and comments on matters of interest in the whole field of science, news of the Association's own activities and reviews of selected scientific books and films.

The range of contents of future issues will—as do the Association's great Annual Meetings—reflect and report progress in the whole field of scientific endeavour.

TELEVISION AND FAMILY LIFE[1, 2]

by

WILLIAM A. BELSON

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Background to the Enquiry

Since television broadcasting re-started in Britain in 1946, the percentage of homes with television sets in them has risen from less than 1 per cent to 70 per cent at the present time. Of those with sets about four out of five are able to view ITV programmes as well as programmes from the BBC. The growth is like this:

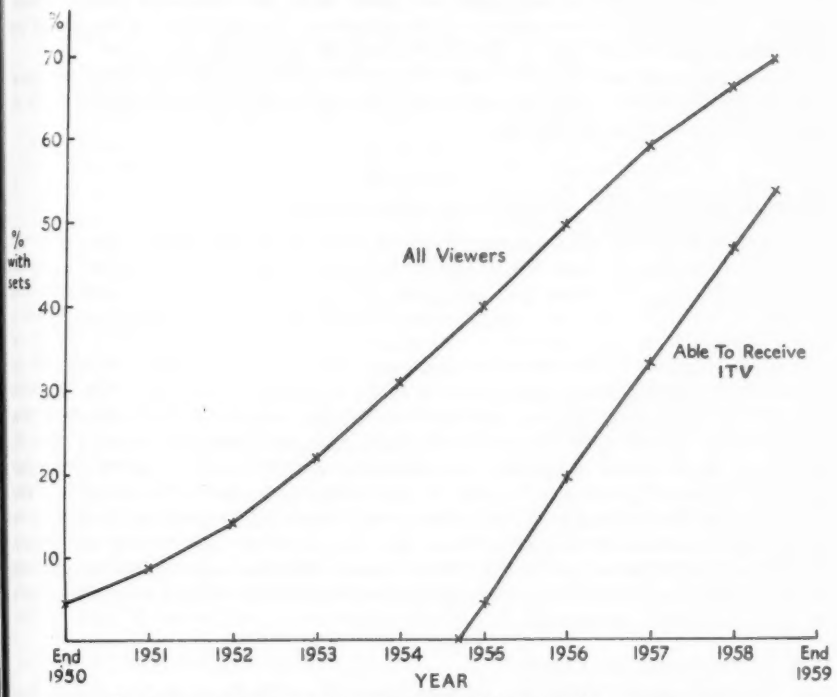

Fig. 1.—Showing growth in percentage receiving television programmes.

Inevitably questions have been asked about its effects and I reported several years ago on one aspect of this.[3] I should like to put some further facts before you now, this time about its role *in family life*. This is not necessarily a statement about

[1] The material in this report is drawn from the writer's forthcoming book, *Television and Society* (Allen & Unwin).

[2] Paper delivered to Section J (Psychology) on September 4, 1959, at the York Meeting of the British Association.

[3] 'The Effects of Television on the Interests and Initiative of Adult Viewers in Greater London' (now in the *Brit. J. Psychol.*, Vol. 50 (2), May 1959).

TV's effects. Rather it is a description of its role in the family setting—a description of the use made of it and the way it enters into the family scene.

My evidence on this occasion is based on the intensive questioning of adults from 150 London families and upon a London survey in which adults from about 400 viewing homes took part. The survey provided a quantitative framework to which the responses of those taking part in the intensive questioning could be linked. In other words, the sample undergoing *intensive* study was matched to the general population in terms of occupational background, type of family and age of respondent.

The Intensive Interviews

Before describing the results, I want to tell you how the intensive interviews were carried out. The method of getting the intensive information was to put people through test-room questioning, in groups. They remained anonymous. They did not know the purpose of the meeting beforehand, and their responses were elicited on the 'secret ballot box' principle. There was a lot of stress on the need for frankness and honesty and they were made well aware of their responsibility for providing a true picture of the situation. Testing went on for about an hour and a half. There was no discussion until all the testing was over.

Now these conditions do not ensure completely honest replies, but both internal checks and the nature of the admissions made suggest that my informants went at least a good way *towards* honesty.

Findings

What are the Physical Conditions under which Families View?

Now it is inevitable that the conditions of viewing should temper the effect of television upon family members. I would like to say a little about what these conditions are. *In the first place*, for about half the viewing families in London, the viewing room is the only communal room which is heated in the winter, and many homes do not have any alternative communal room, heated or not. The effect of this must be to swell the number of people in the viewing room, especially in winter time—for in many cases there is really nowhere else to go. This may be linked to at least some degree with the second fact, which is that relatively few families view with *no lights* on *at all*, and that in half the viewing homes in London, viewing is done in *full light*. This is a situation, notice, which would allow *other* activities to go on in the same room. *A third* thing to notice is that over half the viewing families of London have a large screen (reported by them as 16 inches or more) and that this should allow for a fair scatter of viewers round the room. Finally, we should note that the set is in the dining room in about one viewing home in six—which ties in with the claims of many of my informants that they sometimes eat and view at the same time.

How Discriminating are Viewers?

One would expect all this to have *something* to do with the question of just *how* discriminating people are about their viewing.

Sparing you the statistics, the evidence on this point is that there is an appreciable amount of fairly unselective exposure to programmes by members of the family—due partly to watching what others happen to be viewing; that there are quite a lot of differences of opinion over what will be viewed; that there is a good deal of inattention, by at least one member of the family, to what the others are viewing.

The Scene in the Viewing Room

Having said this about viewing conditions, I want to turn to the question of what it is actually like in the viewing room when the set is on. Suppose you walked

in on the viewing family, unseen, what would it be like? Let me start with a few *carefully selected* case studies.

(1) 'There are four of us in our family and we all have our special chairs for viewing. We usually have the ITV. None of us does anything while viewing—and we don't talk until the programme is ended.'

(2) 'My wife sitting in an easy chair knitting and looking at the programme. My eldest daughter sitting on the settee with a book on her lap dividing her time between the programme and the book. Up to 7.30 my youngest daughter sitting on the same chair as her mother asking all sorts of questions about what is happening on the screen.'

(3) 'My daughter and mother are sitting on the settee watching intently whilst my husband is sitting in an armchair under the window snoozing or reading the paper. I reading the paper with an occasional glance at the programme. If it is very interesting down goes the paper . . .'

As I said, these are selected statements, but they do bring out the fact that what happens is essentially varied. A careful analysis of *all* the statements made *does, none the less*, bring out a number of *recurrent* features of the viewing scene.

(1) The most frequent is one of either divided attention or of people carrying on with something else in the presence of the set.

(2) A recurrent feature of the viewing scene is *silence*, a silence which is often reinforced by shushing and by the general annoyance of the disturbed party.

(3) When talk occurs during programmes it tends to be brief. The break for advertisements is, in many cases, the time for this brief talk.

(4) A good many families hurry to get through meals in time for viewing, and there are quite a lot of cases where meals are eaten in the presence of a TV programme. There is a lot of nibbling and snacking during programmes.

(5) Children are frequently present in the adult viewing circle.

(6) Despite elements of discord, television is markedly an occasion for family gatherings, some of them compact and cosy.

But in case someone takes these six features to depict the *average* scene—and they *do not*—let me say this: What happens varies enormously from one family to another. In *some* families the members will watch it, pretty well in silence, engaging in no other activity, and this may continue for most of the evening with one programme being viewed after the other in a fairly undiscriminating way. In another case, only pre-selected programmes are viewed, and comments are freely made during many of the programmes. Then again there is the household where the set stays on most of the evenings with the family, including children, coming and going—sometimes half attending to it, sometimes doing something else in the presence of the set and mentally tuning in only when they hear or notice something interesting. *What happens is essentially varied.*

Television and Family Co-operation

Let me go now to another aspect of television and family life. Does television affect the way that families co-operate in doing household jobs and in other family activities? Does it affect the way they do things together? Take first the doing of household jobs together.

Television appears to have at least three different kinds of impact on this. For a lot of viewers it means that family members pitch in together and get jobs done before sitting down together to view television programmes. There is something to suggest, in the statements by viewers, that this meeting of a deadline together gives form to the evening, provides a sense of achievement and is specially companionable. An allied arrangement is one where members of the family agree to do various chores on a 'fair shares' basis, during those programmes which do not

interest them. Here again, viewer statements suggest a spirit of team-work in the family.

Another way in which TV can affect the doing of jobs together is that the wife tends to be left to finish off various jobs whilst the family goes in to view. In some homes the 'skipping out' activity of some members of the families is a point of conflict which occasionally becomes high grievance—like this:

'It affects family life quite a lot. The men generally sit around doing nothing (but view) whilst the housewife has to do all the work. She waits on them hand and foot, and all she gets from them is a grunt. By the time she has finished work she is so tired she feels like going to bed and having a good sleep.'

In the third group of viewing families, there is evidence of jobs not done and of their being put off until a more convenient time—sometimes after programmes and sometimes in between programmes.

Apart from household jobs and talking, the hardest hit of family activities appears to be the provision by the family of its own entertainment, particularly the playing of cards. Other things viewers mentioned as marking a fall-off in family activities were: the entertaining of visitors, outings together to friends or to the cinema, joining with the children in play or homework and putting them to bed.

On the other hand, many viewers claimed that television led family members more into each other's company and that they relaxed together more because of it.

The Discussion of Family Affairs

Another aspect of family life is the discussion of family affairs. How does television fit in with this?

At least a third of the London viewers *maintain* that television has little or no effect on the discussion of family affairs and of the day's events (i.e. what the different family members have done during the day).

In many homes, however, television means that discussion of family affairs or of the day's events is displaced into odd moments in the evening.

Quite apart from displacement of this sort, reductions in the *total amount* of it are frequently reported. This can take many forms, but here is one of them—somewhat extreme, but by no means rare.

'When we are viewing, anything that has happened is quickly disposed of in a few words—mainly between programmes. Or my sister and I sometimes whisper little odd things. Likewise my son creeps in and whispers in my ear. If it is important or interesting I join him elsewhere in the house.'

Of course you have to contrast statements like *that* with ones like *this*:

'When we first had television we were too busy viewing to talk, but now we will discuss our day and not trouble to look unless the programme is very good.'

How does Television affect the Way that Parents get on with their Children?

No statement about television and the family can be complete without some treatment of the relations between parents and children.

Here, the situations reported by my informants are essentially varied, ranging from marked friction to something suggesting happiness. Granting that there are many homes in which friction tends not to occur as a result of television, let me list some of its main sources. A lot of viewers report distinct trouble in getting their children to bed. Many more report that early bedtime is achieved only by the exercise of constant firmness. Rebellions about what will be viewed are also reported. So is a certain amount of trouble over behaviour the children pick up from programmes, and over jobs not done by them. Of course, a good many parents seem to turn television partly to their advantage by using it as a sort of bribe for good behaviour.

Some housewives, particularly those with pre-school children, find that the absorption of the child with children's television provides a period of escape from attention to the child. They welcome the break. On the other hand, there is evidence that the absorption of *parents* with television frequently cuts down on normal exchanges between parents and children. This is partly because the children are not encouraged to interrupt the viewing of the parents; but it is also because there is a general cut-down in the time devoted to playing with the children and to talking with them when they are being bedded down for the night. In these cases it is as if television has taken over some of the interest formerly centred in the child. A *new* baby, as it were! But as I said, the situation is markedly varied and there are many homes in which this happens to only a minor degree or not at all.

On the positive side, some parents report an increase in the degree to which their children have something in common with them—programme knowledge, general knowledge, awareness of what is going on in the world around them, and, generally speaking, a broader outlook.

Seeing these Results in Perspective

Now having said this about television and the family, I think it highly desirable that I try to put it into perspective. All my results describe the present *role* of television in family life. What has to be remembered about them, however, is that television's *impact*—its total effect—must be gauged not just in terms of the part it is playing in family life, but in terms also of what things were like before it came. Thus in homes where the wife is left to finish the chores whilst the others go in to view, it is quite feasible that she would have been left to finish them whether there was a television set in the home or not. In the same way, silent circles round the set will often mean that father is at home instead of being at the pub. And shushing and a certain amount of friction in the viewing room may for many have replaced outright discord and conflict. You do not need research to know that, television or no television, family life is not idyllic.

Summing up

Finally, let me sum up. In broad terms, the result of this check is as follows. Television's impact on family life can be considerable, but what happens varies sharply from family to family, and no single (major) statement about effects can apply to them all. Thus, whilst there are many homes in which television appears to produce a distinct disruption of family affairs during the evening, there are others in which it appears to bring the family together in a warm and co-operative atmosphere; and there are others again where its impact appears to be very marginal indeed.

PUBLIC PATRONAGE AND THE ARTS[1, 2]

by

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Introduction

Upon the demise of the private patron of the arts, contemporary opinion has it that the state must move into a new field, hitherto the preserve of the individual spending his private money. Yet this is in part misleading, for there is ample historical precedent for governmental activity in the arts. In classical Greece, there were competitive festivals (agones) of plays and music, the expenses frequently being defrayed by states or communities.[3] Though private noblemen were the principal source of patronage in seventeenth-century Europe, many of the free cities appointed municipal musicians, notably cantors who were in charge of school and church choirs but who also had general municipal duties. Election to such posts was controlled by the town councils, and once appointed 'the musician became part of the municipal hierarchy for life'.[4] Under such circumstances, J. S. Bach became a cantor at Leipzig in 1723, and died in office there in 1750. Yet another (though legendary) example of municipal patronage is provided by the pied piper of Hamelin:

> 'If I can rid your town of rats
> Will you give me a thousand guilders?'
> 'One? fifty thousand!'—was the exclamation
> Of the astonished Mayor and Corporation.[5]

Upon the default of the corporation, the piper provided an unsponsored musical enticement for the children of the municipality.

Nowadays children's concerts are usually administered by education committees, and have thus been excluded from the present survey, along with all other artistic activities having a flavour of formal education. Thus we have excluded schools' museum services, full- or part-time education or training in fine art, music or drama, lectures and classes on these artistic subjects, and most expenditure on community centres, adult education and the like. These things are excluded firstly because they are more easily regarded as part of the educational services and, as such, have been studied by others; and secondly, because it enables us to draw as clear a line as is possible in this rather confused field, between our main interest and the adjacent field of education.

Similarly we have adopted a narrow definition of art, partly for practical convenience as before. We recognise three fields—fine art, music, and a group of activities which we designate as drama, and which includes ballet, opera, musical plays, films and poetry as well as straight plays. Among the state-maintained

[1] Paper delivered to Section F (Economics) on September 4, 1959, at the York Meeting of the British Association.

[2] I am grateful to many who helped with the survey of local authority expenditure; in particular, I should like to thank Mr. Crow (Deputy City Treasurer, Sheffield) and Mr. Hutchinson (National Institute of Adult Education), together with the many local authority officers who replied to the questionnaire.

[3] P. H. Lang, *Music in Western Civilisation*, p. 16 (New York, 1941).

[4] M. F. Bukofzer, *Music in the Baroque Era*, p. 401 (London, 1948).

[5] Robert Browning, *The Pied Piper of Hamelin*.

museums and galleries, we have sought to include only those which are devoted *primarily* to the display of objects whose *raison d'être* is their aesthetic appearance; thus museums of science and natural history, and of certain special subjects such as war and maritime history have mostly been excluded. Among municipal and other local museums, the catch has undoubtedly been more inclusive, only museums clearly devoted to science and industry having been excluded. Expenditure on historic buildings and ancient monuments has been excluded; were it not, it would be difficult to know where to draw the line; there is no implication that this expenditure is not of artistic value. Finally, institutions which are primarily or solely libraries have been excluded, on much the same grounds as before. Expenditure in Northern Ireland is not considered; thus except where explicitly stated, the amounts quoted refer to expenditure in Great Britain.[1]

Within this framework, then, this study describes the amount and nature of public expenditure, discusses some economic aspects of the existing institutional arrangements and examines some suggested alternative arrangements. To urge the spending of more (or less) public money on artistic activities is not the role of the economist, as economist; hence there will be no discussion of whether or not the state should participate in this field, and if so, to what extent.

Statistical Evidence[2]

It is useful to consider first the importance of the sector relative to the economy as a whole: in 1958–9, total net public expenditure in Great Britain in the field here considered, was roughly £5 million, which is about $\frac{1}{40}$ of one per cent of the net national income at factor cost, or, to use another measure, it is approximately $\frac{7}{100}$ of one per cent of total public expenditure in all fields. Because the amount of the expenditure is so unimportant in relative terms, it is often argued that the country can easily afford to increase its spending on the arts. But this is no argument for neglecting to ensure that good value for money is obtained. What it does mean, however, is that we need not examine the side-effects of any increase in expenditure; in other words, the sector is so small that any conceivable increase in spending therein would, *taken by itself*, have no noticeable effect on the rest of the economy; for example, the effects on incentives of raising the extra revenue through higher taxation and rates could safely be neglected.

Of this total expenditure of £5 million, just over half was undertaken by central government, the remainder being administered by local government authorities and charged to local rates (see Fig. 1). Taking central and local government together, two-thirds of the total was spent on fine art (almost all of this being devoted to art museums and galleries), approximately one-eighth on music, and the remaining one-fifth on opera, ballet and drama (an important part of this expenditure being the Arts Council grant to opera and ballet).

On examining central government expenditure in earlier years, we find that, even after allowing for the rise in the level of prices, the total has grown appreciably. But much of the increase has been devoted to extending support to other activities, rather than to increasing expenditure in the original fields. Until the last decade, almost all central government expenditure was concentrated on the state-maintained art museums and galleries, whereas in 1958–9, only 54 per cent of the total was so directed. Among the new interests, opera and ballet received 25 per cent of total expenditure, leaving 21 per cent to be divided amongst

[1] It has not been possible to assess the amount of support given to the arts through the loss of tax revenue caused by the various exemptions granted to artistic activities.

[2] For more detailed statistics, together with an account of the sources and methods of calculation, see another version of this paper published in the *Yorkshire Bulletin of Economic and Social Research*, Vol. 11, No. 2.

all other activities. Despite this extension of the field, expenditure on the state-maintained art collections does seem to have increased in real terms in the last two decades, except possibly for expenditure on acquisitions[1] and new buildings.

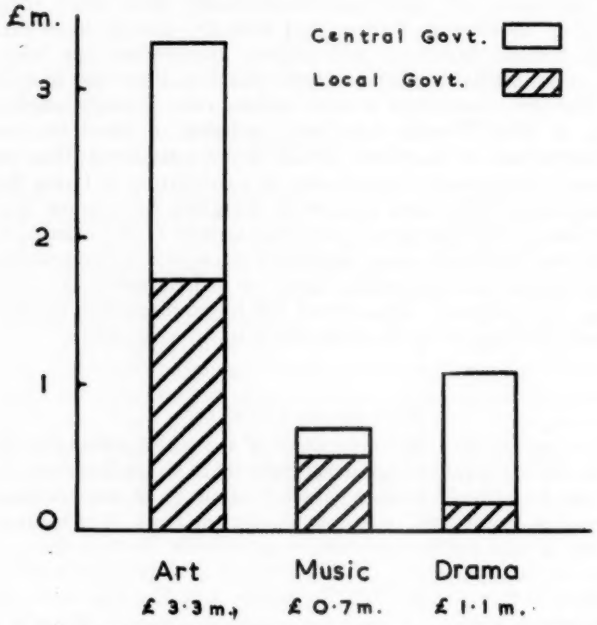

Fig. 1.—Estimated net public expenditure on the arts in Great Britain, 1958–9.

The rough calculations embodied in Fig. 2 (*a*) suggest that when measured at constant prices the wage and salary bill (which currently accounts for more than half of the total expenditure on these collections) has increased by about 40 per cent since the 'thirties. When the net fine art expenditure appearing in Class IV of the Civil Estimates is expressed as a proportion of the national income (see Fig. 2 (*b*)), the figures increase in recent years after the lean war period, but reach only the level of the 'thirties.[2]

Most local government expenditure is undertaken by the larger authorities. In England and Wales the typical county borough maintains a museum or art gallery, occasionally buys some extra pictures for it, spends modest amounts on music and very small (net) sums on drama. Apart from Greater London, there is relatively little expenditure elsewhere; most of the relevant statutes exclude county councils from the field, and most of the urban and rural district councils are too small to take much interest in most art forms, though some do maintain museums. In Scotland, the four large cities spend considerable sums in all three categories, but in the other large burghs only a minority have a museum or gallery, and expenditure on the other arts is very small indeed. In quantitative terms, net expenditure in the county boroughs as a whole appears to be roughly equal to the

[1] Because of obvious practical difficulties, no attempt has been made to measure changes in the value in real terms of the grants for acquisitions made to the state-maintained collections. It should be noted that critics have commented adversely on their present size, claiming that they have not kept pace with art prices.

[2] In the pre-war years, the proportion appears to have counter-cyclical tendencies, as one might expect.

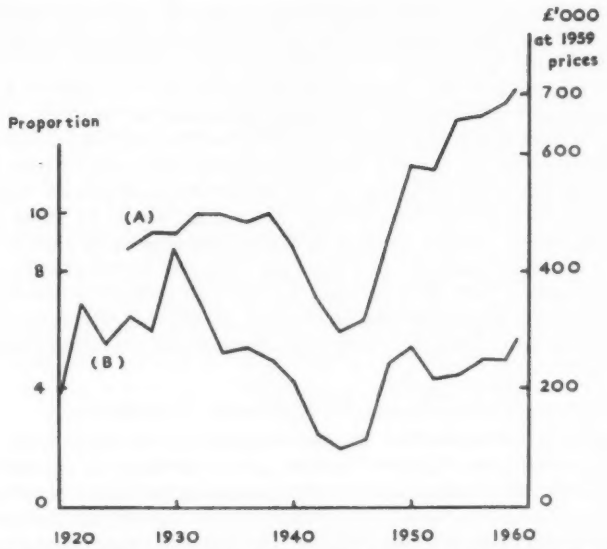

Fig. 2 (A).—Expenditure on wages and salaries in the state-maintained art collections, 1926–59, measured at 1959 Prices.
(B).—Fine art expenditure voted in Class IV of the Civil Estimates, as a proportion of U.K. national income, 1920–59. (The units are thousandths of a percent.)

yield of a 2*d.* rate, of which three-quarters is devoted to fine art. In the Scots large burghs as a whole, the corresponding rate is 1¾*d.* and some 60 per cent of this is devoted to fine art (for some details, see Fig. 3).

When *gross* expenditure on fine art in the county boroughs and large burghs is classified according to the use to which it is put, slightly more than half goes to employees in municipal museums and art galleries, only 5 per cent or less being

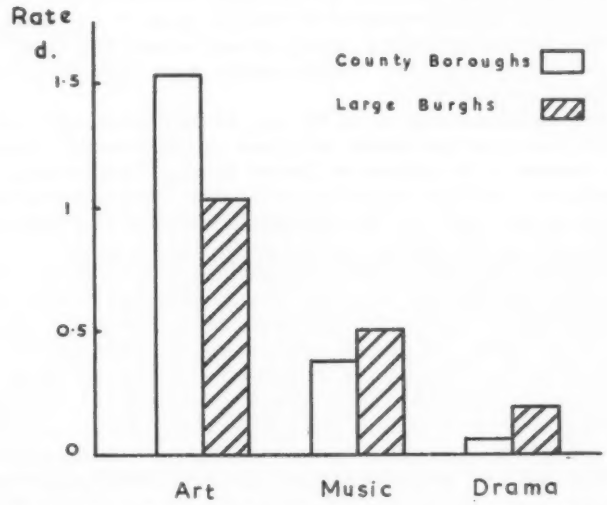

Fig. 3.—County boroughs and large burghs: net expenditure as a rate, 1958–59 (units: pence per £ of rateable value).

spent on acquisitions for these collections; grants to voluntary bodies represent not more than 2 per cent of the total. Of the corresponding total for music, however, about one-third in England and Wales, and one-half in Scotland, is devoted to such grants to independent bodies, major items being the various schemes for assistance for the symphony orchestras, and municipal subsidies for festivals. An important part (in the county boroughs, almost one-fifth) of the total expenditure on music is the deficit incurred (on current account) on municipal concert-halls largely as a result of hiring out these buildings at nominal or reduced rentals; such subsidies are awarded to both municipal and independent activities. In gross expenditure on drama, the Scots pattern appears to differ markedly from that in the county boroughs. The explanation is, that because very few authorities spend any appreciable amounts in this field, the county borough pattern is heavily influenced by expenditure on municipal entertainments in the holiday resorts, while the Scots figures are dominated by grants to independently organised festivals.

Monopoly and Geographical Dispersion

The arguments put forward by economists against monopoly apply even more strongly than usual in the case of the arts, where diversity of opinion and hence dispersion of control over expenditure are essential to the health of artistic activity. We have already noted the small proportion of total expenditure on fine art which is disbursed in grants to voluntary bodies. Despite this, control can be said to be well dispersed; in most of the state-maintained collections, the system of trustees ensures at least some artistic independence. The considerable expenditure on local museums is divided amongst many groups, and the larger authorities at least are capable of pursuing vigorous and independent policies. In music and drama, however, there has been more criticism; according to our estimates, approximately 60 per cent of net public expenditure in 1958–9 was controlled by the Arts Council, and some critics have expressed dissatisfaction with the dominating position of the Council.[1]

The problem of control has no simple solution. It should be noted that the Arts Council undertakes very little in the way of direct provision, and that most of its money is disbursed in grants to other bodies. Were there no Arts Council, and were these other bodies supported directly by grants-in-aid, there would still need to be some form of centralised control, possibly taking the form of a Treasury committee. Money granted from a single source must necessarily be subject to unified control at some stage.

On the problem of the division of the Arts Council's cake (another source of dissatisfaction), we note that about one-third of the Council's expenditure in 1958–9 was devoted to the support of Covent Garden. It is perhaps worth considering whether it would be desirable to make that opera house the subject of a separate grant-in-aid, while the Council would continue to support opera and ballet in other places. The change might help to disperse control in that sphere, central government expenditure then being divided between these two bodies.

Another major criticism has been that central government expenditure is too heavily concentrated on London, so that provincial taxpayers are subsidising the inhabitants of the capital. To provide statistics here is rather difficult since some organisations which receive grants, work partly in London and partly elsewhere. However it seems that in 1958–9 approximately two-thirds of central government expenditure was devoted to activities taking place in London, 17 per cent to those in the rest of England, 11 per cent to Scotland, and 6 per cent to Wales. Expenditure in these last two countries was mostly concentrated in Edinburgh and

[1] For a recent cricitism voiced in the House of Commons, see *H.C. Debates*, July 13, 1959, Vol. 609, cols. 170–8, especially col. 175.

Cardiff respectively. It is also interesting to note that in two capital cities where there is considerable central government expenditure on museums and galleries, there is correspondingly less support for such institutions from the local government authorities, than might otherwise be expected.

There are indeed many strong arguments for the geographical concentration of *central* government expenditure,[1] yet it seems fair to comment that such concentration is more marked in Great Britain than in the rest of Europe, though this may do no more than reflect greater concentration of population. Local government expenditure presents (and in our view, rightly so) a different picture; almost all such spending is directed to activities taking place within the boundaries of the financing municipality, though there is of course nothing to prevent the ratepayers of one authority benefiting from the expenditure of an adjacent authority. There is one major exception to the rule that local money pays for local pipers, namely the various schemes whereby local authorities join together in regional groups to subsidise a symphony orchestra. In the main, the size of the contribution of an individual authority is related to the service it may expect from the orchestra, so that even here there is little redistribution. We cannot agree with the view (apropos the scheme which supports the Scottish National Orchestra) that 'a most admirable feature of this scheme is that so many of its participants are places too small to be able to receive the orchestra yet willing to accept the principle of collective responsibility for a national institution of the arts'.[2] If there is to be redistribution, then central government taxation would appear to be a more appropriate vehicle than local rates, though it must be admitted that the latter method assists in the dispersion of control.

Local Government Expenditure

We have already remarked that it is difficult to avoid centralised control of central government expenditure, and we have just referred to the obvious corollary that dispersion of control can be assisted by increasing the role played by the numerous local government authorities. At present, however, local patronage is fairly limited; as we have seen, little more than half of the total public expenditure is so financed, and in the joint field of music and drama the proportion is less than two-fifths, despite such activities being available, in the main, only for people living near the place of performance. Under Section 132 of the Local Government Act, 1948, most types of local authority may undertake *net* expenditure not exceeding the product of a 6*d.* rate (in Scotland,[3] $4\frac{4}{5}d.$) on

(*a*) the provision of an entertainment of any nature or of facilities for dancing;
(*b*) the provision of a theatre, concert hall, dance hall or other premises suitable for the giving of entertainments or the holding of dances;
(*c*) the maintenance of a band or orchestra;
(*d*) any purpose incidental to the matters aforesaid . . .

Thus the Act permits such expenditure but does not *require* local authorities to provide entertainment or dancing. Art galleries and museums were established under earlier Acts, and our remaining activities, music and drama, cover most of the field envisaged in the 1948 Act; yet the estimates suggest that the county boroughs, for example, spend on music and drama about $6\frac{1}{4}d.$ per head of their population, which is slightly less than the product of a $\frac{1}{2}d.$ rate, compared with the 6*d.* rate permitted in the Act. Nor is there much evidence of increased activity

[1] See Sir William Emrys Williams, 'The Arts and Public Patronage', *Lloyds Bank Review*, July 1958, especially pp. 22–4.
[2] Williams, *op. cit.*, p. 21.
[3] The lower figure here does not imply that the Scots are less interested in culture, but merely reflects the higher level of valuation prevailing in Scotland at the time of the passing of the Act.

on the part of local authorities during the last few years,[1] despite the new undertakings of a few individual authorities. It may well be that, as in the case of the libraries and the art galleries, municipal provision will require several decades of slow growth before it becomes a major force.

There is one way in which local assistance may be given to voluntary artistic bodies without the need for the local authorities to take the initiative; this is through the provision for relief from local rates. Section 1 of the Scientific Societies Act, 1843, lays down that societies instituted for purposes of the fine arts exclusively, shall not pay rates on their premises, while Section 8 of the Rating and Valuation Act, 1955 (for England and Wales, with similar provision in a 1956 Act for Scotland), gives local authorities power to reduce the rates of non-profit-making bodies active in various fields, including the arts. These provisions have been thought by some[2] to be of great value since the form of assistance can be sought by a new body as soon as it is established, whereas other forms of financial aid are frequently confined to long-established bodies. The amount of the subsidy to the arts accorded by the 1843 Act is not susceptible to measurement, since the buildings and land of bodies qualifying under the Act are not entered on the register of rateable values and no rating assessment is made. The qualifications for relief under the recent Acts are less stringent, but relief is confined to any extra rates which might otherwise have been payable as a consequence of the new scheme of valuation. Answers to the questionnaire suggest that the amounts involved are very small indeed; for example, of the 50 county boroughs who replied, 34 stated that they granted no relief, 8 disclosed amounts up to £50 per borough, and 8 reported larger sums. Such bodies as received relief were mainly theatres and various arts societies; one might expect museums and galleries to receive more important subsidies, but most such buildings are municipally owned and hence not eligible for relief under the 1955 Act. The museums maintained by voluntary bodies are, of course, exceptions to this, and some of the larger ones (e.g. the National Museum of Wales) receive considerable relief.[3]

Estate Duty and Taxation

The introduction of estate duty, income tax and surtax has led to a marked diminution in those stores of private wealth which, in the past, assisted the private individual to patronise the arts. Thus it seems appropriate to maintain special taxation rules which differentiate in favour of the arts, and we shall now examine these.[4]

Firstly, annual donations of money under deed of covenant to voluntary artistic organisations attract relief from income tax in most cases, but not from surtax. Secondly, works of art are exempted from estate duty so long as they continue to be enjoyed in kind (Finance Act, 1930, s. 40 (1)); if the works are then sold, estate duty becomes chargeable on the proceeds, unless the sale is to a national artistic institution, a university, or a municipal body (Finance Act, 1930, s. 40 (2)), provided that in the case of a sale to such a body, exemption is granted only if the sale is by private treaty (Finance Act, 1958, s. 31). And finally, works of art of

[1] For some results of a survey of expenditure in England and Wales in 1956–7, undertaken by the National Institute of Adult Education, see *Adult Education*, Spring 1959, pp. 243–7. Comparisons between the published results of the survey and the present estimates are hindered by the differing definitions used, especially in the fields of music and drama.

[2] See, for example, *H.C. Debates*, Jan. 23, 1959, Vol. 598, cols. 570–1.

[3] Recently the Pritchard committee has recommended certain changes in the rating law; briefly, these are that all charities should be assessed for rates, that they should be entitled to a mandatory relief of 50 per cent of the rates payable, and that local authorities should have discretion to remit part or whole of the other 50 per cent. See *Report of the Committee on the Rating of Charities and Kindred Bodies*, Cmd. 831 (H.M.S.O., 1959).

[4] See also: *Government and the Arts* (H.M.S.O., 1958), paras. 59–66; *Standing Commission on Museums and Galleries—Fifth Report*, 1954–8 (H.M.S.O., 1959), pp. 9–11; *Help for the Arts* (Gulbenkian Foundation, 1959), para. 100.

'pre-eminent aesthetic merit or historical value' may be accepted in satisfaction of estate duty (Finance Act, 1956, s. 34).

The effect of these rules is that individuals are given incentive to spend more of their own money on art than they would in the absence of the reliefs and exemptions, in such a way that much of the benefit of the expenditure eventually accrues to the public at large. These rules are justified (on economic grounds alone) if the *extra* expenditure exceeds the cost to the government sector of the taxes and duties forgone. Where this is so, then the alternative of not allowing any such reliefs and exemptions and arranging for the extra revenue from taxation to be spent on artistic enterprises through existing or new state institutions, would by itself reduce the aggregate amount spent on artistic activities available to the public. Further, the present system of encouraging private patrons to spend money on the arts means a wider variety of patronage than is likely under the alternative system of state expenditure.

The provision for exemption from estate duty of the proceeds from works of art sold to approved bodies by private treaty, interferes with the otherwise-free market system in an interesting manner. Suppose that the executors of an estate have in their hands a picture which, it is believed, would fetch £100,000 on being auctioned, and that the estate is such that estate duty would take for the government sector, 40 per cent of this sum; then the executors are (financially) indifferent between sending the picture for auction, or selling by private treaty to an approved body for £60,000, since this smaller sum represents the net receipts which would accrue from sale by auction. Not surprisingly, some of the national collections began offering private treaty arrangements at the lower figure (in our case, £60,000) thereby leaving the private owner without any inducement to sell to an approved body[1]; more recently the Chancellor of the Exchequer advised those concerned to deduct from the market value, 75 per cent of the value of the exemption thereby leaving 25 per cent of this value with the executors. Thus, in our case, the approved body concerned would offer £70,000 to the executors, and this sum is not liable to estate duty. The picture thereby passes to the government sector at a price below its free-market price, but the government sector does not press its monopoly powers to the full. A similar rule applies to the 'price' at which a work of art is accepted in satisfaction of estate duty.

Until the passing of the 1958 Finance Act, when a national museum or gallery bought a work of art at an auction, and where the proceeds of the sale would have been liable to estate duty if the work had been sold to a private buyer, then the government sector paid the full market price. With the qualification added in this Act, the monopoly powers are here used to the limit; out of the £100,000 receivable for our hypothetical picture, £40,000 would be paid in estate duty, under the conditions we have assumed; the net price to the government sector would then be £60,000, but one important institutional point must be noted: the museum or gallery concerned would need to find the full £100,000, the estate duty being received in a different government account.

Recently, the Government has been urged to extend this list of differential taxation rules. Two suggestions are that donations under deed of covenant should attract relief from surtax (thereby restoring the privilege removed by the Finance Act, 1946) and that other donations should attract relief from income tax, under certain circumstances.[2]

Specialisation and the Artist

The part-time professional musician or actor seems to have virtually disappeared from the contemporary British scene; we conclude by speculating on whether or

[1] *Government and the Arts*, paras. 64–5.
[2] See the Standing Commission report, *op. cit.*, p. 11.

not his return would assist in the provision of musical and dramatic performances in smaller communities. Whilst the players concerned might well cry out that such a practice would cause a lowering of professional standards, it is perhaps worth referring to historical precedent. As municipal cantor at Leipzig, Bach's duties included the teaching of five Latin classes each week,[1] whilst several members of the orchestra directed by Haydn at the Esterhazy court, worked also as domestic servants in the royal household.[2]

Today, even some quite large cities do not provide full-time work for an orchestra or repertory company; perhaps the economic problem of indivisibility can be circumvented by the players taking other work which, unlike the historical examples quoted, is related to their artistic performances. For example, one might establish a repertory company which played in alternate weeks, while some or all of its members were part-time teachers of English in some of the local schools. The individuals concerned would require both a university degree and a professional dramatic training; undoubtedly some persons exist who would be both able and willing to undertake both types of work, and the merging of the two roles might well prove to be of mutual benefit to standards in both spheres. There does seem, at the least, to be scope for useful experiment here; the problems of practical organisation could probably be minimised by having the same employer in both types of work, namely the local government authority.

[1] Philipp Spitta, *Johann Sebastian Bach*, Vol. 2, pp. 190–7 (London, 1899).
[2] R. Hughes, *Haydn*, p. 42 (London, 1950).

THE ORIGIN AND METABOLISM OF RADIOACTIVE MATERIAL IN THE HUMAN BODY[1]

by

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INTRODUCTION

THE METABOLISM of radioactive materials by the human body has in the last few years become a subject of increasing public and scientific interest due to the development of great industries depending upon such material for the production of power and to the testing of atomic and nuclear devices. Yet our knowledge of the levels of naturally occurring radioactivity existing both in and around mankind throughout his evolution to date and of the factors which control the distribution of such material in the human body, is extremely scanty. Such knowledge is essential before any sound judgment can be made either now or in the future as to the significance or otherwise of any artificial radioactivity which may be produced.

There is no doubt that sufficiently high levels of radiation can and do produce cancer and genetic changes in man, though this has been most directly shown in certain types of fly and small mammals. There is equally no doubt that the problem of radiation hazards should not be taken out of its context and regarded as a new and menacing phenomenon. The problem should be viewed in perspective against the much wider background of environmental radioactivity in which we live and have evolved long prior to man's experiments with artificially produced radioactive materials.

A few years ago, therefore, we embarked on a programme aimed at defining levels of natural activity in man, identifying the elements concerned, investigating their origin and studying the various plant, animal and human metabolic pathways involved in their distribution.

EXPERIMENTAL TECHNIQUES

On looking at the literature concerned with human radioactivity it is clear that the early workers had not the technical means of detecting or identifying the levels of natural activity present in plant, animal and human tissues and before commencing it was necessary to develop improved methods of observation. Much of the natural radioactivity is due to the radium and thorium series, each of which contains a number of alpha-particle emitters of biological importance capable of being detected at very low levels. The work has proceeded along parallel lines, one aimed at measuring the radium and thorium series by a simple, cheap and rapid method of counting alpha-particle emission, and the other aimed at positive identification of the elements present by measurement of the alpha-particle energies, i.e. alpha-ray spectroscopy. Both these techniques have been described by us elsewhere.

The specimens are normally examined in the form of mineral ash resulting from

[1] Paper given to Section A (Physics) on September 8, 1959, at the York Meeting of the British Association.

furnace treatment of the starting material at 600°C. When the activity is at a sufficiently high level the material may be measured without ashing.

For measurement of the alpha-activity due to the radium and thorium series a layer of 1 mm. or so of ash is placed in intimate and permanent contact with its own zinc-cadmium sulphide phosphor and sealed in a shallow cylindrical container comprising a perspex ring with transparent Scotch tape forming the top and bottom surfaces. The alpha-scintillations produced in the phosphor are counted with the help of a photomultiplier tube and conventional scaling circuits having very high long-term stability. The limit of sensitivity of the arrangement is of the order of 0·03 $\mu\mu$c per gram of sample, which is several times lower than the lowest alpha-activity so far found in the ash of any plant, animal or human tissue.

The absolute accuracy of the measurement is about ± 5 per cent, which is more than adequate in a field such as this where the activities range over 100 million to 1 and where there is usually no biological significance to be attached to changes of 10 or 20 per cent in a particular parameter. With this technique we have measured thousands of specimens of human bone and soft tissue, human excreta, animal tissues, plant materials, soils, waters, foods, tobaccos, pharmaceutical products and environmental materials.

For more positive identification of the alpha-emitting elements present, we use a large ionisation chamber as a pulse counter with the emitter sprayed in the form of a 1 or 2 micron layer on a thin aluminised plastic sheet lining a large cylinder containing a methane/argon gas mixture. Such a thin layer does not appreciably absorb the alpha-particles, which therefore emerge into the gas volume with very nearly their full energy, characteristic of their parent atom. Electrical pulses whose amplitudes are proportional to the energy of the particles are therefore produced in the chamber and are fed to a 100-channel pulse analyser which sorts them according to amplitude and displays them as an alpha spectrum. With this technique we have produced the alpha-ray spectra of human tissues, foods, plants, etc.

Alpha-particles have initial velocities of the order of 50,000 to 100,000 miles per second, and their penetration into tissue is limited to about one-twentieth of a millimetre, whereas the much lighter beta-particle, with similar velocity, may penetrate tissues to a centimetre or so. In view of the density of ionisation associated with the short track of the alpha-particle it is generally accorded a relative biological efficiency of five or more with respect to a beta-particle of the same energy. In other words, the alpha-particle is often regarded as five or more times as effective biologically as a beta-particle of the same energy, but this factor is variable, depending on many circumstances.

The Natural Radioactivity of Human Tissues

(*a*) *Bone*

Human beings occupationally exposed to the ingestion of high levels of radium over a long period of time have been found subsequently to have abnormally large amounts deposited in their skeletons. Radium is, therefore, regarded as a 'bone-seeking' element and, for many years, a total body content of $\frac{1}{10}$ microcurie (i.e. 100,000 $\mu\mu$c) has been regarded as the maximum permissible level above which there is an increasing probability of permanent damage, even malignant conditions, being produced in the bone.

In the past there has been considerable controversy as to the total amount of radium normally present in the human body. Early workers put the value as high as 10,000 $\mu\mu$c concentrated in the skeleton, i.e. only a factor of ten times down on the maximum permissible level, and many were of the opinion that the value increased throughout life. The soft tissues of the body were regarded as containing very little radium and the possible presence of the thorium series seems rarely to have been considered.

Fig. 1 shows the results of measurements we have made on some seventy specimens of human bone derived from the London area, Cumberland and Cornwall. Even in this limited number of specimens there is a variation of at least 10 to 1 in the values found and no relation is apparent between radioactivity and the age of the subject. We do not seem to grow more active as we get older. Even more surprising, twelve measurements made on full-term still-born infants show values of activity per gram bone ash much the same as in the adult.

Since the total alpha-activity of the bone ash includes a contribution from the thorium series, the actual value of the Ra226 in each case is about one-seventh of the total activity. The mean Ra226 is, therefore, about 0·06 $\mu\mu$c per gram bone ash, which for an average body content of 2,000 to 2,500 grams of mineral ash gives a

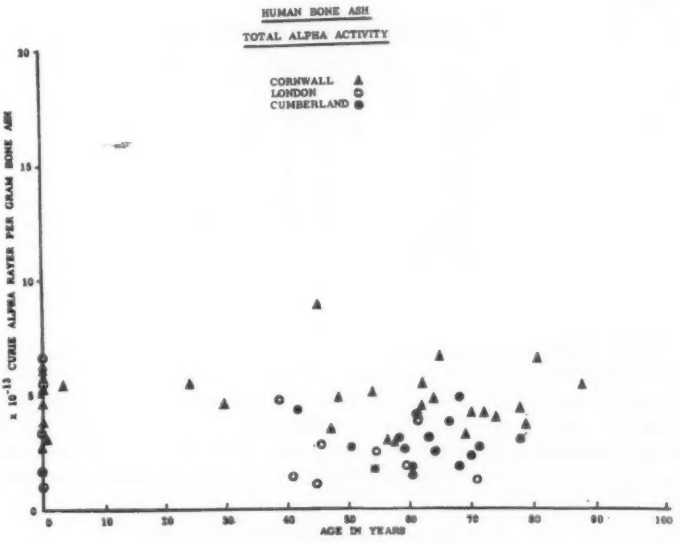

FIG. 1.

total Ra226 burden of 120 to 150 $\mu\mu$c. This value is in close agreement with that recently found by American and other workers and is lower by a factor of about 800 than the maximum permissible level of 100,000 $\mu\mu$c.

The highest activities in this series were found in the Cornish material, and it is tempting to associate this fact with the known high uranium content of the soils in some parts of that county. As we shall see, however, the enormous variations found between the natural radioactivities of common foods may be of much greater significance in determining the skeletal radioactivity.

(*b*) *Soft Tissues*

In the case of human soft tissues, where the activities per gram of wet tissue are much lower than for bone, the problem of measurement is rather more difficult. Here, again, the material is ashed, and since soft tissue contains on average about 1·5 per cent mineral matter, a concentration of activity of approximately sixty times is achieved compared with three times in the case of bone.

Table I shows mean values obtained for a number of human tissues. We see that the highest activities found so far have been in the hair, lungs and thyroid. In the case of the hair, where the value is relatively high, we do not yet know how much

of this activity has been metabolised into the hair and how much results from absorption or adsorption directly from the atmosphere. The lungs may well have also derived part of their activity directly from the atmosphere, this activity being attached to particles trapped by them and subsequently taken by phagocytic action into their appropriate lymph node system.

With regard to the thyroid, it is interesting to note that next to bone the thyroid contains the highest concentration of barium so far reported in human tissues, barium being an element whose chemical properties are very similar to radium.

With these exceptions the activity so far found in soft-tissue ash is sensibly the same as that found in bone ash, and would seem to indicate roughly uniform contamination by the radium and thorium series of the mineral building blocks used

TABLE I

TOTAL ALPHA ACTIVITIES OF HUMAN SOFT TISSUES

	No. of Samples	μμ curie per Gram Ash
Lung	5	0.77
Liver	7	0.33
Kidney	4	0.26
Thyroid	1	0.84
Heart	5	0.28
Muscle	5	0.51
Spleen	6	0.40
Pancreas	2	0.18
Uterus	2	0.30
Bile	2	0.21
Brain	4	0.15
Testis	1	0.23
Prostate	1	0.30
Hair	11	2.00

by the body. Taking into account their relative mineral contents, this implies a ratio of about 20 to 1 between the alpha-activity per gram of wet bone and per gram of wet tissue respectively. Since the total mass of wet tissue is approximately six times that of bone, it appears that something like 25 per cent of the total body radium and thorium is present in the soft tissue with about 75 per cent in the bony skeleton. This is a somewhat different picture from that generally accepted hitherto.

METABOLIC EXPERIMENTS AND FOOD

In an attempt to discover the origins of the body's natural radioactivity and what fraction of the ingested activity was retained by the body, a metabolic-balance experiment was attempted.

For a whole month we ashed and measured the naturally occurring radioactivity of everything eaten and drunk by a normal healthy 3½-year-old boy. It is to be emphasised that no radioactivity of any kind was added and no change made in his normal diet. At the same time the total amount of radioactivity excreted daily by him throughout the period was measured. Fig. 2 shows the total radioactive input and output daily throughout the period.

Bearing in mind the logarithmic vertical scale used for the daily intakes and excretions, it will be seen how greatly the intake of radioactive material varied from day to day. By eating certain types of cereal for breakfast high values were obtained, whereas a different choice of diet resulted in the radioactive intake being reduced by factors of 10 to 20. The general time pattern of excretion follows that of the intake but delayed usually by twenty-four and sometimes forty-eight hours.

This experiment provided the first hint we had that most of the natural activity which goes in, comes out again, even in the case of a young child undergoing rapid skeletal development. When these results are plotted in an integrated form as in Fig. 3, it appears that this child apparently retained approximately 20 per cent of the month's total ingested alpha-activity. The values of activity found among the

many foods involved in this experiment provided a number of surprises and demanded further investigation on a wider scale.

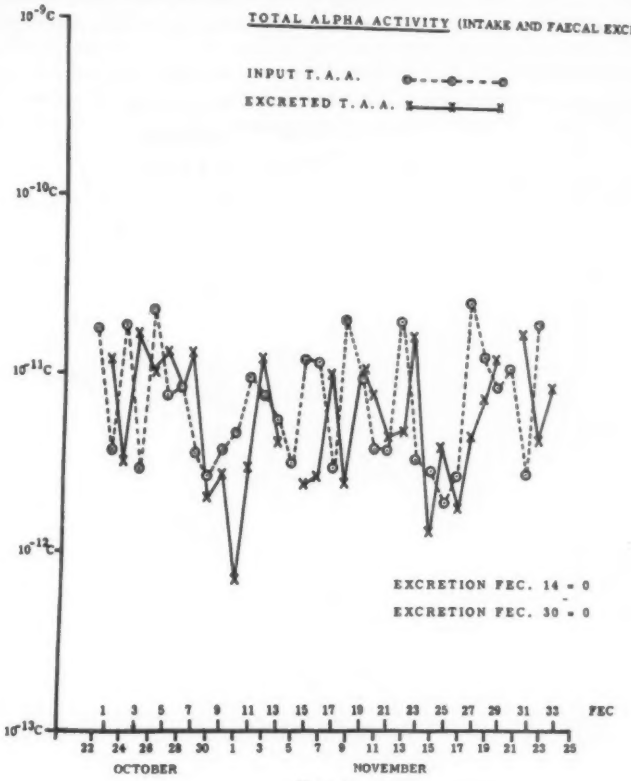
TOTAL ALPHA ACTIVITY (INTAKE AND FAECAL EXCRETION)
INPUT T. A. A.
EXCRETED T. A. A.
10^{-9}C
10^{-10}C
10^{-11}C
10^{-12}C
10^{-13}C
EXCRETION FEC. 14 - 0
EXCRETION FEC. 30 - 0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 FEC
22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25
OCTOBER
NOVEMBER

FIG. 2

The results of many hundreds of measurements we have made on foods commonly available in this country are summarised in Table II, which lists some of the main categories and their activities.

TABLE II

FOODSTUFF	MAXIMUM α ACTIVITY OBSERVED PER 100 GRAM (μμc.)
BRAZIL NUTS	1700
CEREALS (BREAKFAST)	60
SHELLFISH	30
LIVER & KIDNEY	15
FLOUR	14
PEANUTS	12
CHOCOLATES	6
BREADS	3
BISCUITS	2
MILK PRODUCTS	1-2
MEATS & FISH	1-2
FRUITS & VEGETABLES	<0.1

It will be seen that a very wide range of natural activities exists in our ordinary foods, the ratio of the most active to the least active food so far examined being at

least 20,000 to 1. In general, fruits and vegetables have very low values of natural radioactivity, with milk and meat slightly higher. The most active type of food met with in bulk is cereals, but the radioactivity of Brazil nuts is most surprising and some forty times higher still. The nuts have an absolute radioactive content such

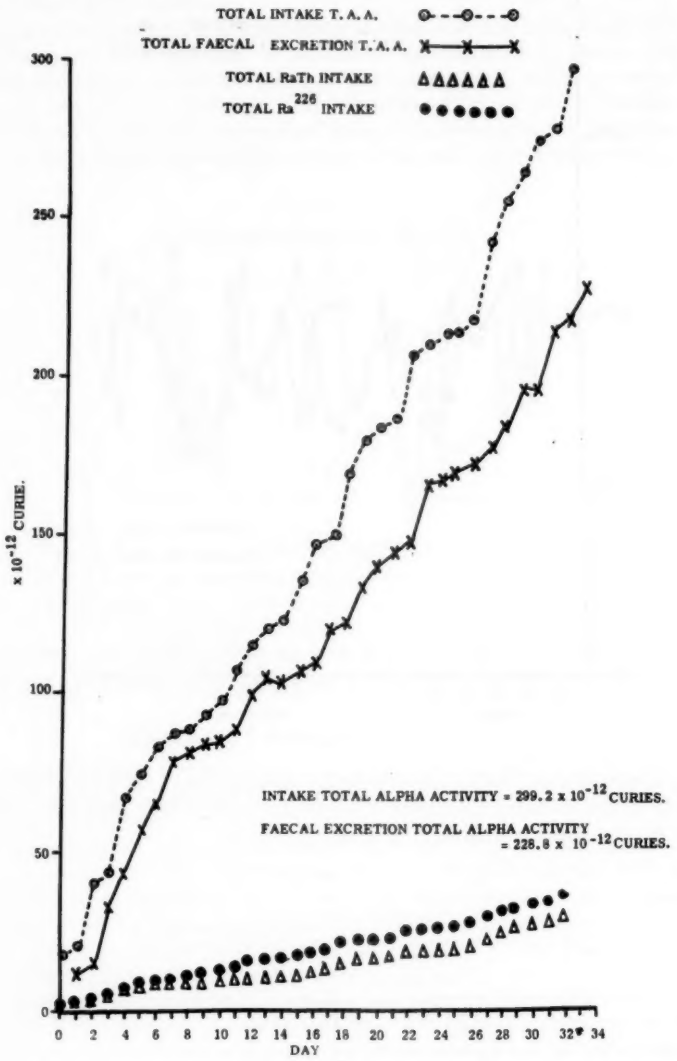

FIG. 3.

that 4 oz. possess three times as much radium and thorium as the entire bone and soft tissue of the normal adult human body.

It is apparent that in a population such as ours with a very wide range of available foods, the individual daily intakes of natural radioactivity can differ as widely as the tastes of the individuals themselves. It is interesting that in any ordinary English family there can easily exist among its three or four members regular daily

intakes of natural radioactivity differing by factors of many hundreds or even a thousand to one.

The descending order of activities in the groups of foods is similar to the pattern of their contents of heavy trace elements. It has been known for twenty-five years that the Brazil nut contains up to 0·3 per cent by weight of barium, so that, as in the case of the human thyroid, we have an association of radium and barium.

Fig. 4 shows what we believe to be the first radioactivity spectrum of a foodstuff, that of the Brazil nut, displaying the various members of the radium and thorium

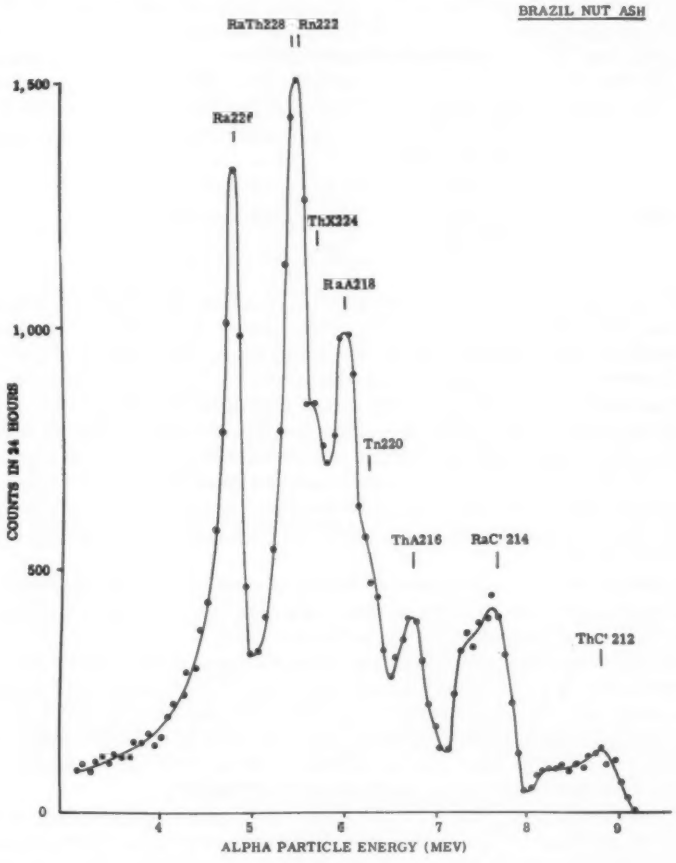

FIG. 4

series. The spectrum is typical of the results found for the foods so far examined in this way and provides unequivocal evidence of the elements responsible for the radioactivity.

It is interesting to compare the daily intake of natural radioactivity revealed by our measurements in one or two different types of diet, with the daily intake of strontium 90, the artificial radioactive nuclide which has been most discussed in relation to radiation hazards. Table III attempts to place these numbers in perspective. The strontium 90 represents a 5 per cent increase (in terms of $\mu\mu c$) of activity on diet 2, but no allowance for differences in particle energies or relative

biological efficiency has been included in the Table. Since the mean alpha-particle energy is 5·6 times that of the mean beta energy of strontium 90, and the relative biological efficiency may be as high as 5, the figures for natural activity would have to be multiplied relatively by 28 in assessing potential biological effects. In other words, the strontium 90 daily intake would represent a fractional increase of 1 part in 300 in terms of potential biological effect for this particular diet. In relation to the diet containing Brazil nuts, the strontium 90 contribution is of course relatively much less. Moreover, as we have seen, the skeletal content of radium can vary by a factor of 10 to 1 among the individuals of a small group.

TABLE III

DAILY INTAKE OF RADIOACTIVE BONE SEEKERS IN U.K.

		Alpha Activity μμc.	Beta Activity μμc.	Gamma Activity μμc.
NATURAL SOURCES				
Diet 1	High in animal protein. No cereals or nuts.	3 - 4	0.5 - 1.0	0.5 - 1.0
Diet 2	High in carbohydrate. No nuts.	20 - 100	18 - 22	18 - 22
Diet 3	High in carbohydrate with protein and fat derived from brazil nuts instead of animal tissues.	1000 - 3000	220 - 440	220 - 440
ARTIFICIAL RADIOACTIVITY.				
Strontium 90 "Fall out".		Nil	6 - 7	Nil

Apart from food, there is, of course, a second medium by which the human body can acquire naturally occurring radioactivity, namely water. Here our data so far are not nearly as comprehensive as for foods and the investigation is still in its early stages. However, we are already aware that certain waters in this country contain levels of natural activity forty or fifty times higher than others. The range may ultimately turn out to be greater than that, but the absolute values of activity are such as to make it seem unlikely that the contribution from water will compete with that from foods except in special localities and in cases where the dietary content is at the lower end of the activity scale. We must, however, bear in mind the possibility that the body may find it much easier to retain radioactive material present in soluble form in water.

There seems, therefore, no longer to be any mystery about the immediate origin of the natural activity found in the human body. The mystery lies in how the human succeeds in keeping his radioactivity to the low level of 100 to 200 $\mu\mu$c of Ra226, i.e. 600 to 1,200 $\mu\mu$c of alpha-activity, in spite of intakes which can be of that order of magnitude per day. The 'equilibrium' between the body content of radioactivity and that of its environment is clearly a dynamic one and more research is required into the physiological factors determining real intake and utilisation of these materials by the body. The relation between the activity in the body and that outside it, does not appear to be a simple proportionality.

Before considering the origin of the great range of natural activities present in human foods, perhaps we could turn for a moment to some other facets of our radioactive environment which have little direct bearing on food and water intake but which under certain conditions could be responsible for increased ingestion of natural radioactivity. We have made measurements of the natural alpha-activity of a considerable number of environmental materials with which man has surrounded himself and which are now regarded as necessary to him in his civilisation. Fig. 5 shows the activities of a few such materials.

The values cover a range of more than ten million to one, with the most active environmental material being the luminous timepiece, which contains upwards of 2 or 3 μc, i.e. 2 or 3 million $\mu\mu$c of radium and thorium series. Here, of course, the alpha-particles cannot penetrate the glass front, but the same is not true for the beta- and gamma- activity. Then we have the incandescent mantle, which is almost pure

thorium dioxide with a specific activity such that 1 milligram contains more bone-seeking alpha-, beta- and gamma-activity than the entire human body. It requires little imagination to see how flakes having this high activity could in earlier days have been ingested with food. Then we discovered an anti-nausea pharmaceutical product designed for use by pregnant women. The recommended daily intake of tablets contains about 13,000 $\mu\mu$c of high-energy alpha-activity with corresponding levels of high-energy beta- and gamma-activity, but we have, so far, no evidence of the retention of this material in the human.

Then we have the automatic-lighter flint with an alpha-activity of 3,000 $\mu\mu$c per gram, so that each time we light a cigarette we shower our faces with 3 or 4 $\mu\mu$c of the same high-energy naturally occurring alpha-, beta- and gamma-activity. We have powders for polishing lenses, with activities of 200 to 300 $\mu\mu$c per gram, and we use superphosphate fertilisers with about the same level of activity. Certain types of dental fillings were found to have similarly high activities, but these, we understand, have now been withdrawn.

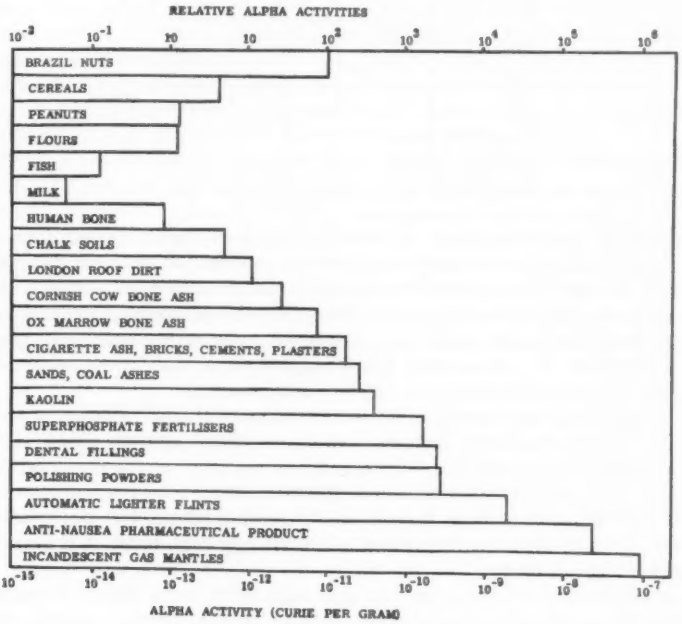

FIG. 5

Since kaolin or china clay is found in Nature associated with uranium, all pottery and crockery and sanitary earthenware contain radium and thorium at about this same level, such that 10 grams has the same total alpha-activity as the human body. Certain types of glassware and glazes are coloured by the use of uranium compounds, and even some papers owe their glaze to materials containing the same radium and thorium series at easily measurable values. Coal and cigarette ash, bricks, cements and plasters all contain about 20 $\mu\mu$c per gram, so that an ounce or so of these materials has the same total alpha-activity as the human body.

It is clear, therefore, that we live in a remarkably radioactive environment and that this has been so for a long time. Yet in spite of this the human somehow contrives to keep his natural radioactivity to the very low levels we have observed.

Perhaps we can return for a moment to the origins of the activities present in human foods. From our measurements on soils, humus, plants and animal bone and soft tissues, there are emerging one or two clues as to the underlying fundamental pattern.

Table IV summarises our measurements so far on the natural activity of the bone ash of a few animal species derived from different parts of the world. There is a

TABLE IV

MEAN BONE ASH VALUES (SPECIES)

SPECIES	ORIGIN	T. A. A. $\times 10^{-14}$ C/GRAM ASH	$RaTh/_{Ra}$
Sheep	Wales	> 1900	1.1
Camel	Sahara	1100	0.31
Ox (Marrow bone)	U. K.	1000	0.4
Rabbit	U. K.	880	0.5
Sheep	Argyllshire	840	0.4
Deer (Antler)	N. Scotland	380	0.3
Deer (Mandible)	U. S. A.	380	0.34
Cow	U. S. A.	340	0.23
Cow	Cornwall	320	0.34
Sheep	N. Z.	200	0.46
Sheep	U. K. (1921)	140	< 0.10
Horse	U. K.	38	< 1.0
Man		32	0.65
Chicken	U. K.	27	< 1.0
Pig	U. K.	15	-
Dog (Puppy)	U. K.	9	0.3

range of 200 to 1 in the values of activity found in these few samples. Man is apparently among the less active species. It is interesting that all the higher values are for herbivores, with Welsh sheep the highest so far observed, at a level sixty times higher than man. We have already seen that the most active human diets are those high in plant tissue, and it could therefore be that the eating pattern of the animal largely determines its subsequent bone activity, although there might well be fundamental species-differences operating simultaneously.

Two interesting points emerge from our studies of the soft tissues of sheep and cows, namely that the livers and the kidneys of these animals show very much higher activities than the muscle. The second point concerns the remarkably higher specific activity found in the eyes of both these species. It has been known for some time that certain types of cells present in the animal retina, but not possessed by the human, tend to concentrate barium at a relatively high level. A radium/barium association is, again, evident.

Our measurements of soils, humus and vegetation from different parts of the world have also produced some interesting facts. In general, the variation observed between soils is relatively small, only about 8 or 10 to 1, whereas the humus and the vegetation vary over a considerable range not only in their alpha-activities but also in their relative contents of different members of the radium and thorium series. There does not appear to be any immediate simple relation between the activity of the underlying soil and that of its top humus and vegetation.

In the vegetation, we have found the radioactivity to be present at higher levels in the foliage, with the fruit invariably having very low activity. The high values found in many leaves (up to a 1,000 times higher than the fruit of the same plant) are due largely to the radium series, the plant seeming to be able to discriminate against the thorium series in spite of its greater abundance in most soils.

The herbivores can evidently have very high intakes relative to man, but in the case of the cow and the sheep their metabolic processes appear to act selectively against the deposition of the material either in their milks or in their muscle, at the

expense of its excretion or deposition in their bones and to some extent in their livers, kidneys and eyes. Man, drinking their milk and eating their meat, acquires very little natural radioactivity in the process.

In areas which have been cultivated infrequently or not at all, the humus must largely be the result of the decay of countless generations of plants which have lived and died at the particular site. Each plant, in its turn, has made its own selection from the radioactive materials available to it. These successive processes of selection over very long periods of time result in the top humus acquiring radioactivity which is quite different in concentration and in composition from that of the underlying soil.

On the other hand, areas which have been subject to continuous and intensive cultivation for long periods show this phenomenon to a lesser degree, and the plants have, in our observations, therefore, much lower activity.

To summarise:

(1) The variations in level of radium and thorium so far observed in the bone and soft tissues of a number of individuals are small compared with the immense variations observed in man's foods and in his environment. What factors control the relations between these sets of levels of activity and determine their absolute values we do not yet know.

(2) The distribution of activity in certain organs of man, the cow and the sheep, as well as the activities present in human foods, appear to follow the general pattern of deposition of trace amounts of heavy elements such as barium.

(3) Of man's basic foods, meat and milk are low in natural activity, probably as the result of selective mechanisms operating in the animals concerned. Fruit and vegetables have low values as the result of analogous mechanisms operating in plants whereby the radioactivity is put into the foliage and not into the fruit.

(4) Finally, it is clear that in the disciplines of human, animal and plant physiology, there are many problems concerning the distribution of natural radioactivity and the part it might play in normal metabolism and evolutionary processes. These problems, at once fascinating and fundamental to mankind, await the effort, initiative and skill of our younger scientists.

THE DIRECTORY OF NATURAL HISTORY AND FIELD STUDY SOCIETIES

THE Council of the British Association for the Advancement of Science have, at the invitation and with the financial backing of the Carnegie United Kingdom Trust, prepared a new edition of *The Directory of Natural History Societies* which was first published in 1948 by the Amateur Entomologists Society.

The Directory, which was published during 1959, covers archaeological, astronomical, biological, botanical, geographical, geological, meteorological and zoological societies, both national and local amateur bodies—and other cognate societies. The information given for each society is listed under the following headings: title and address, name and address of Secretaries, aims and objects, conditions of membership, amenities, meetings, publications and affiliations. Societies are arranged alphabetically under the main headings of natural history, archaeology, archaeology and natural history, societies with general interests, geology, astronomy, and meteorology. The arrangement of the societies within the sections is strictly alphabetical according to the titles supplied by the Secretaries. There is a final geographical reference section in which the names of the societies are listed alphabetically according to counties. This geographical section has been compiled so that naturalists moving from one district to another may be able to get into touch with others having similar interests.

The Council of the Association hopes that the publication of the *Directory* which contains information about some 800 societies will stimulate field studies throughout the country and, by increasing the possibility of co-operation between professional and amateur scientists, will make a real contribution towards our understanding and appreciation of the world in which we live.

Copies of the *Directory* may be ordered (20*s*., plus packing and postage 1*s*. 6*d*.) from The Secretary, British Association for the Advancement of Science, 18 Adam Street, Adelphi, W.C.2. A limited edition of interleaved copies is available at £1 5*s*., plus packing and postage 1*s*. 6*d*.

THE TRAINING OF TEACHERS OF SCIENCE AND MATHEMATICS: WHAT THE SCHOOLS REQUIRE[1]

by

DR. K. LAYBOURN, M.Sc.

Chief Inspector of Schools, Bristol

IN SECONDARY schools of all kinds the teaching of science and mathematics is hampered and often hamstrung by the shortage of properly trained men and women. Academic qualifications of science staff in grammar schools are at the lowest ebb for fifty years. The national position is well known and I shall not rehearse it, but some account of an enquiry made this year into the numbers and qualifications of science teachers in my own city may be of interest. When teaching recruitment is being discussed, Bristol ranks as a 'lush' area; for more than one reason it has proved an attractive city in which to work.

At Easter, 1959, Bristol had 31 modern schools, 10 bilateral, 2 technical (admitting at age thirteen) and 18 grammar (of which 7 are maintained schools); the total secondary-school population was 30,000. The bilateral schools have grammar and modern streams; these schools are of recent growth, so that at the time of the survey none yet had a sixth form. Most of the modern schools are developing five-year courses leading to an examination at age sixteen, the Secondary School Certificate of the Union of Educational Institutions. There are more than 1,600 pupils in grammar-school sixth forms.

In these 61 secondary schools, 211 men and women were teaching science, either as their main subject or alongside other subjects. Among them were 132 science graduates, but 60 of these had neither a First- nor a Second-Class Honours degree. No man, and only one woman, had graduated with a First during the last five years. Twenty-four of the graduates were from Oxford or Cambridge, but only 5 of these had qualified during the last five years and none of the 5 was teaching in a maintained school. It is evident that there is a very bad age-structure in science staffs; the more highly qualified men and women are not being replaced and the direction of science departments will inevitably weaken.

As would be expected, nearly all the graduates were teaching either in grammar or bilateral schools. Only three remained in modern schools, and all three had been teaching for more than twenty years. Of the 51 men and women sharing the science in Bristol modern schools, at least 22 lacked specialist training of any kind; they neither graduated in science nor took it as a main subject in a training-college course.

When the enquiry was made, Heads reported sixteen vacancies for science staff, three of them in grammar schools. Many of these will have been filled for the opening of the new school term, but the position brought about by resignations and retirements during the course of a year is very damaging. One-third of all the teachers of science in Bristol secondary schools have served for not more than a year in their present posts.

Owing to the greater difficulty of recruiting women for science, the subject is usually in the hands of men in the mixed schools. Two-thirds of the science teachers

[1] Paper delivered to Section L (Education) on September 3, 1959, at the York Meeting of the British Association.

in the city are men and more than half of the women science teachers in modern schools did not take science as a special subject at college.

So much for qualifications. Now let us take a look at the *quantity* of science teaching. Here it is helpful to consider the relation between the number of pupils in a school and the total hours of teaching time given to science in that school:

$$S = \frac{\text{Total hours of science on the time-table}}{\text{School roll}}$$

The *effectiveness* of the science teaching will depend upon other factors too, such as the size of classes, the staff teaching load, and laboratory facilities. Most of all, it will depend upon the quality of individual members of the staff. Indeed a cynic might say that S stands for the lip-service paid to science; yet it is a useful first indication of the place of science in a school.

The average figures for grammar schools in Bristol are given below:

Type of school	S
Maintained grammar	0·16
Direct-grant grammar	0·21
Independent grammar	0·21

In a school of 500, $S = 0{\cdot}16$ corresponds to eighty hours of science teaching, requiring four full-time members of staff. With a Science Sixth of forty, and classes of thirty in the rest of the school, this is just about adequate—certainly not generous. Factors of class size and a wider variety of science options probably account for the high S-value in some non-maintained schools; but values of S lower than 0·16—such as occur in a number of girls' schools—can only indicate fewer science periods in the time-table.

In modern schools, lacking sixth forms, we can say with confidence that the minimum time allocation for effective science teaching would be an average of three periods per class per week. Assuming classes of thirty pupils, this gives $S = 0{\cdot}07$. Introduce extended courses with some science bias at the top of the school, and S approaches 0·09. Here are actual averages in Bristol:

Type of school	S
Boys' modern	0·07
Girls' modern	0·04
Mixed modern	0·04
All modern schools	0·05

At the British Association Conference on Science in Schools held in London a year and a half ago, Dr. B. E. Lawrence referred to a review of 1,500 modern schools, from which it appeared that, on average, not more than 1½ hours a week was being given to Science. With classes of thirty, this gives an S-value of 0·05.

It is clear that science does not occupy a commanding position in the time-tables of most modern schools. In fact it gets on average about 6 per cent of the school day. This means either that the number of periods allocated to it in most modern schools is ludicrously small, or that the subject does not appear at all in the programme of certain classes. Both circumstances arise. They do so because conditions in even the best-equipped modern schools have never made it likely that the schools would attract or hold trained specialist teachers. We have now reached a position in which a fraction of our grammar schools—a select few—can secure teachers with good Honours degrees in science for all their science posts. In other grammar schools there is immense difficulty in finding such people and increasing numbers of Pass degree and college-trained teachers find their way onto the staffs. This in turn leaves many modern schools without science specialists of any kind.

The real situation is far more alarming than is generally supposed, for we are on a most precipitous downward slope. Where science teachers are on the whole less competent to deal with their subject than are teachers of other subjects, perhaps less able intellectually, science does not take the place in the curriculum that it should; the more able pupils are not attracted to its disciplines; and the profession of science teaching falls into disrepute. Plans to increase the numbers of university and training-college places and of men and women taking specialist science courses will not of themselves put this matter right. Certainly we need far more teachers, but the essential problem is one of quality.

The position in mathematics is little different, though in one sense the evil effects may be even more fundamental. In Departments of Education the proportion of men students with 'good honours' degrees in mathematics is very low; in the case of women students the supply of graduates of any kind is insufficient to fill the known vacancies in grammar schools. Such a situation has clear implications in relation to the sixth-form teaching that is required as a key factor in any programme of scientific and technological expansion. But it also has clear implications for the modern schools: the best of the men and women from the new three-year specialist courses in the training colleges will not be available to such schools, which will be left with the average and less-than-average and with non-specialists. In the 1956 survey conducted by the Association of Teachers in Colleges and Departments of Education it was shown that the great majority of women's colleges had few or no students taking mathematics as a specialist subject; indeed one-third had no graduate mathematics lecturer. The significance of this appears when we recall that women are forming an ever-increasing proportion of the staffs of primary and modern schools. Upon them much of the arithmetic and mathematics teaching must inevitably fall. In the primary schools they will have responsibility for the early training of those able children who later proceed to grammar schools and who will form the reservoir from which our future teachers will be drawn. The attitude of such children towards mathematics must be strongly conditioned by what is done or not done at the beginning. Yet of the women students admitted to training colleges in recent years, only about half had reached the 'O' level stage in mathematics. Few of the remainder had any effective knowledge of mathematical processes and many had 'dropped' the subject early in their grammar-school courses. If mathematics teaching in primary schools is in the hands of teachers without any real feeling for it, embarrassed by ignorance, can we wonder that so many prospective students avoid it?

Two things need saying again and again. First, that only those who have studied a subject for themselves can teach it well: there must be the love and understanding that stem from real knowledge. This basic requirement has too often been glossed over. In constantly recurring emergencies we have tended to rely upon the conscientious teacher to keep one or two jumps ahead of the class; we have too easily assumed that 'a good teacher can teach anything'. There are thousands of very good teachers, but we have not been able to give effective teaching in science and mathematics to the majority of boys and girls.

The second thing is that knowledge of a subject, even in a man or woman with good general teaching ability, will not alone guarantee success. The aims and purposes of the teaching programme must be seen in clear relation to the abilities and needs of the pupils who are being taught. Too often in this respect we continue to move in a circle traced out fifty years ago. The content of what is taught and the method of teaching it in secondary schools of all kinds, so far as science and mathematics are concerned, are still dictated very largely by techniques developed for success with the ablest pupils in grammar schools. We are beset by a system which places emphasis on the theoretical side; by syllabuses which tend to preserve what is traditional, reflecting the teacher's own text-book training; and by teaching

techniques which take little account of the needs of young people who do not love learning for learning's sake.

There are two ways of teaching science. In the one, statements are made and the pupil is exhorted to understand and learn them. Practical work, such as it is, is conducted as an illustration of the statements; but the real authority is the text-book. It is this method that has dominated the schools in the first half of the twentieth century, in spite of the efforts of many of the best teachers to bring about reform. To it we can trace much of the university criticism of sixth-form students, for the method is fundamentally illiberal. It is known to be almost completely ineffective with less able boys and girls; yet it is almost universally practised. Here and there keen teachers, fortunate in their schools, have taken another line. This is based upon the belief that science is not merely information, or even laws and the application of laws; but that it is a way of looking at things and dealing with things, founded upon personal observation and personal participation. Where this approach has been used, youngsters have seen science as the research worker sees it, though necessarily on a different plane. The subject has been exemplified by the way in which it is taught. To this method there is another recommendation, of cardinal importance. The 'ordinary pupil' learns best by doing; his interest is aroused by what is 'real', and reality for him is usually material and closely connected with the events and experiences of his daily life. Such pupils—tomorrow's citizens—need to use their hands and eyes and ears in the service of their minds.

The need to educate the scientists and technologists of tomorrow is everywhere recognised. But our duty towards these other boys and girls is no less urgent. Without our aid they will remain strangers in their own world. Our task is to familiarise them with the reasoning and the reasonableness of science, so that they will grow up neither entirely ignorant of its methods nor totally afraid of its products.

The first essential is a syllabus designed specifically for the kind of pupils that we have in mind. Too often the content of 'general science' courses is a re-hash of text-books that have undergone no fundamental change in thirty years. Our syllabus material must be of intrinsic interest, it must point the lessons that we wish to convey, and it must be susceptible to the kind of treatment that our teaching methods demand. As to this last requirement, we may note that during recent years the gap between the practising scientist and the teacher of science has been widening rapidly. There is a far more extensive repertoire of laboratory demonstrations in connection with pre-1900 science than in the case of more modern work. The discoveries of the twentieth century are often expressed in mathematical language; unless they can be expressed also in the language of common experience they must remain beyond the understanding of the ordinary citizen. Much research is needed, in universities, colleges and schools to see what areas of modern scientific knowledge might usefully be considered when syllabuses are being framed—and what items in the traditional science schemes no longer justify their place. The teacher-in-training stands in urgent need of advice about the content of science schemes. Because of the severe limitations upon teaching time, selection may be critical.

We have postulated that our material must be of intrinsic interest to the ordinary boy and girl and that our pupil's everyday experience should be our main guide. Obviously then the teacher's own knowledge of science must be broadly based, extending into all the main branches. Only then will he be in a position to extract what is most significant from any realistic situation. The man or woman who knows no physics, or no biology, or no chemistry, is at a crippling disadvantage in trying to teach science in a modern school.

How is this knowledge to be secured? It is surely wrong to assume that the training colleges must bear the sole responsibility, even within a three-year course. Their preoccupation must be with professional training—teaching method in the

broadest sense—and for this they need students already reasonably well prepared both in subject-knowledge and in attitude. These students must come, in the main, from the grammar schools; yet the present position is that sixth-form science courses do not really cater for pupils who will take science as a main subject at training college. The academic and largely impersonal atmosphere of pre-university science work is unsuited to such boys and girls. They come to regard it, not as interesting in itself, but merely as a passport to college entry. It has too readily been assumed that salaries are the final determinant against teaching as a profession, but in fact rejection often stems from the pupil's experience at school; he recoils from the prospect of spending a lifetime in drilling apparently useless facts into unenthusiastic minds.

The liberalisation of grammar-school science courses, with the needs of those who might become teachers clearly in mind, would be a powerful first move in the fight to solve the problem now facing us. Beginning from a general treatment, the three main sciences should be carried right through into the Sixth, though not necessarily all to 'A' level. Their interdependence and interplay should be stressed everywhere and the lesson that science is a method rather than a body of knowledge driven home. Much attention should be given to everyday applications of science—but in the sense of problems to be studied rather than of examples to be learned. The history of science should be studied, especially its recent history, so that boys and girls may feel the thrill of contact with great men and recent discoveries. Always the effort must be made to display science as what Sir Cyril Hinshelwood has called 'an imaginative adventure of the mind', though based upon careful observation and experiment. Nor would such a programme come amiss for those abler pupils who will proceed to universities and perhaps enter teaching through Departments of Education. Indeed, if this very desirable development is to take place, the grammar schools themselves will require men and women trained in just this way. It is here that the vicious circle of science teaching must be broken; for we must feed into the training colleges students who see science as a human activity, and who see science teaching as a very human and personal affair.

With this part of the problem laid squarely upon the grammar schools, and with an insistence upon a broad treatment of content right up to sixth-form level, the task of the colleges becomes clear. It is, first, to introduce their students to a kind of school—the modern school—of which grammar-school pupils know very little. Then, to inform these students that academic teaching is a highly unrewarding operation so far as most of the pupils in such schools are concerned. Finally, to insist upon the absolute need for a method of teaching that is likely to have a real prospect of success with average boys and girls.

The question of teaching method is crucial. The key factor is the pupil's personal participation at the practical level. His interest must be aroused and his attention riveted in this way. The main basis of the work will be work in the field or garden; observation of natural phenomena, with associated recording; the investigation of working apparatus and real machines, and the construction of models; carefully arranged visits, such as involve pupils in much personal discussion; and a great deal of small-group experimental work in the laboratory.

The corollaries are obvious. First, that the student-in-training in a main science course must carry at least one aspect of science study to a very high level. Only so will he apprehend the real meaning of the scientific method, the discipline of observation and the rigour of proof. Only so will he be weaned from the error of presenting science as an accomplished body of fact. In a chosen field, perhaps a topic study, the student should advance his academic knowledge to the limit, read deeply in the literature, and carry out a significant programme of experimental investigation. This is the work upon which his own love of science should grow.

The second corollary is that the training college must undertake the technical

training that is necessary if students are to apply the teaching method that has been recommended. Successful group practical work, for example, involves highly skilled laboratory organisation—the provision, storage, distribution and maintenance of stock; the planning of work-schemes and their implementation; the establishment of discipline in an active environment; the steady routine of lesson preparation, insistence upon good records and upon a clearly-seen product of the practical work. Confidence in such matters will come only with experience, but a carefully devised course in laboratory organisation can do much to help the student. The very high rate of teacher transfer, referred to earlier, means that often quite inexperienced people will find themselves in charge of a subject.

Alongside the problem of laboratory organisation is that of the practical skill of the teacher in working with apparatus. One of the greatest contributions to a solution of the desperate problem of staffing in science departments would be the provision of laboratory assistance on a really generous scale. It is really quite astonishing that the economics of the existing situation have not been understood by hard-headed members of education committees. If it is agreed that laboratories built at considerable cost should be used to the full, the need for technician help is surely obvious. Without it, one of two situations arises: either the teacher is employed on jobs that should be done by a laboratory assistant at half the salary; or (and this is what usually happens) practical work by the pupils is reduced almost to vanishing point because the teacher cannot be given the very considerable preparation time that is required. Here is one direction in which the product of science teaching could be improved immediately. The lines have been laid down in an excellent report of the Science Masters' Association, and training schemes such as those approved by the Institute of Science Technology ensure that the work of a laboratory assistant need no longer be a dead-end job.

The point is not generally appreciated, however, that the teacher himself must be something of a craftsman if the best use is to be made of technical assistance. Only then are the resources of the laboratory likely to be deployed to full advantage. The results of the Bristol enquiry indicate that the great majority of science teachers are completely untrained in the use of tools and the manipulation of materials when they first come into the schools. What is required is a carefully planned course extending over a fairly long period, during which manual skill can develop. It must be conducted by craftsmen who are also teachers. Is there any reason why a training college should not work in close association with a local technical college (where one exists) to ensure that science students are no longer denied this vital component of training?

Laboratory facilities are still very unsatisfactory in many modern schools, but the overall situation is rapidly improving as new secondary schools are being built. Less attention has been paid to an equally deplorable situation in colleges and departments of Education, where the numbers, size and equipment of science laboratories are often grossly inadequate. It is to be hoped that the errors will not be perpetuated in current expansion programmes. If teaching of the kind that I have described is to be made possible, students-in-training must spend a great deal of time in laboratories, workshops and gardens.

The absolute necessity of a long practical training for teachers of science will surely force fundamental re-thinking of college courses. But even apart from this time element, there is everything to be said for much closer integration of a student's general educational studies with the study and practice of his special subject. How better can he understand the significance and application of principles than through the subject that he intends to teach and that commands his deepest interest? I should like to see education courses related to main-subject courses far more closely than is commonly the case, although I am bound to confess that the full implementation of such a reform must hang upon improvement in the staffing of training

colleges—for there are at present few education lecturers who have qualifications in either science or mathematics.

We are unlikely in the foreseeable future to get anything like as many specialist teachers of science as we would like. More than ever, therefore, the emphasis in training must be upon quality, and it will be far better to concentrate advanced science courses into a few well-equipped and appropriately-staffed colleges than to try to spread our limited resources more widely. It is time to declare that science is not a subject that can be taught effectively by non-specialists at the secondary level. To compromise on this issue is to reject the whole aim and method of science teaching as I understand it.

The same is true of course of mathematics. There is general agreement in the colleges on certain principles: the unity of the subject, the importance of treating mathematics as a language, the value of the practical and visual approach, and the need to proceed through the child's personal experience. It is accepted that mathematics should be used and seen in action before the relevant operations are discussed and explained. But in the schools at least it is not always apparent that equal emphasis has been put upon the outcome of the work—upon the fact that perception must of absolute necessity involve the intellect and that it is the mental product that justifies the sensory procedure. It is comparatively easy to train teachers in mechanical methods, and 'learning-through-experience' can become mechanical if the learning part is neglected. It seems that we have recognised the shortcomings of the older methods of teaching mathematics without always appreciating that 'teaching-for-understanding' requires that the teacher himself understands! Ministry Pamphlet No. 36 rightly remarks that little progress can be made in overcoming the fear of mathematics until teachers of very young children are themselves sufficiently secure and confident in their own mathematical prowess to be able to meet their pupils' difficulties with understanding. What is true at the primary level is equally true of later stages, yet the results of a recent survey showed that three out of every four teachers of mathematics in secondary modern schools in Manchester had no special qualifications in the subject. I would strongly support the efforts now being made in some colleges to give *all* students 'a basic course in mathematics in which the main emphasis is on the understanding of the fundamental principles of elementary mathematics and the teaching of mathematics'. Such training might enable many teachers of junior children to overcome their lack of specialist knowledge; only the disastrous effect of a public examination in arithmetic at 10-plus would then remain to bedevil all our early effort. But the need for men and women who have soaked themselves in mathematics, who have real competence themselves in the subject, and who have specialised in the study and practice of ways of teaching it, is no less than in the case of science. We shall need them not only as departmental Heads but in all the classrooms if children are to be made aware of mathematics as 'a subject of developing ideas rather than a collection of isolated and incomprehensible rules'. As with science too, we must recognise that students who specialise in mathematics at college ought to spend a high proportion of their time on the subject. There must be a similar determination to use interest in the special subject as a vehicle for general training.

The possible role of the primary schools in science education is much discussed today. Although science is found occasionally in the time-tables of top junior classes, in most primary schools the sole concession to scientific interest is a period or so of nature study. The standards of such work vary enormously. In the best cases children do much for themselves, growing plants in and out of doors, caring for animal pets, keeping diaries and other records of events, forming collections of many kinds, and joining in expeditions and visits. Elsewhere content is sometimes depressingly limited: the same wild-flowers, unidentified shells and inevitable tadpoles make their appearance year by year. There can be no place for formal science

in a primary school; but entire neglect of topics known to be of interest to youngsters is obviously wrong. The questions that children ask are sufficient indication of the catholicity of their tastes, and they range into the physical as well as the biological fields. The aim of what we do will not differ from the aim of other primary work: we shall plan to arouse interest in the world around, to encourage really close 'looking at things', to introduce the use of simple tools through model-making, to practise various ways of recording actual experience, and to give children the satisfaction of achievement in a job well done. The primary school is the right place, at the right time, for foundations of this kind, and it is for this reason that one welcomes the suggestions that have been made for training substantial numbers of non-specialist teachers of science through a main course at the 'B' level described in the Ministry Pamphlet No. 34.

Mathematics and science should be important components of general education in the second half of the twentieth century; yet in England at least we have failed to secure an effective place for either in many of our schools. With the coming of three-year training it is timely to ask why this should be so. Of course there are many reasons and responsibility lies in more than one direction; it is difficult, for example, to see how we shall ever get the kind of science teaching that we want until classes for practical work are small and until we provide the technical assistance that is so urgently required. But the ultimate solution must be closely concerned with teacher training, for only when teachers see more clearly what is required and how it may be tackled are we likely to get a body of opinion that can bring about real change. The reason for this was stated a quarter of a century ago, in a report on the conditions affecting the teaching of science in secondary schools:

> '. . . we come back always to the same point, namely the quality of the teacher. This covers much more than a man's academic qualifications; it is a matter of outlook, and of standards of work and of laboratory management, of knowing what to do and how to do it. If unsatisfactory conditions may do much to discourage a keen teacher and to diminish the efficiency of his work, it is no less true that good conditions are thrown away on the man who does not know how to use his opportunities.'

A COMPARISON OF THE PREFERENCES OF YOUNG CHILDREN AND ADULTS IN DECORATIVE DESIGN[1]

by

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THE INVESTIGATION I want to report sprang from an interest in the ways in which people's preferences among complex designs come about. In an earlier investigation (1955) I have shown that people from different cultures differ very much in the designs they prefer in a series of black-and-white designs based on West African decorative motifs. The people within each cultural group showed a strong tendency to agree with one another in their preferences. The problem then presented itself of how this agreement comes about; the most likely explanation being in terms of social learning and the relatively greater familiarity of some design themes. The difference might conceivably be innately determined, but this seems unlikely on the face of it and the sort of explanation which can only be considered when all other possibilities have been excluded. Nevertheless it seemed well worth while to explore the early years of life in order to see whether young children of different cultures agree in their preferences more closely than adults, and to examine the development of agreement within the different groups.

With this in mind I selected a series of patterns from North American Indian decorative work in the British Museum. Most of them were worked in porcupine quills on belts or moccasins or other articles of clothing. The attribution of the articles was generally a little vague, but it seems likely that they were mainly Woods Indian or Huron Indian. The designs are shown in Fig. 1. Designs A, B, D, E, F and G were based on decorative patterns used repeatedly in these articles. The remaining two designs, C and H, were taken from Pueblo pottery, also in the British Museum. (In my opinion these two designs are more interesting than the others as the Pueblo culture shows a much greater level of development and sophistication in this respect than the Huron Indian culture.) The Woods Indian designs were taken from three periods:

1. Two designs, E and F, were dated around 1850 or before; these were the earliest I could obtain and show a variant of the weave pattern so common in primitive cultures the world over.

2. Designs A and D, dated around 1900, begin to show a marked Western influence. The use of embroidery cotton instead of the traditional materials also suggests the influence of a Western educational system.

3. Designs B and G, the two remaining patterns, are roughly contemporary, dating about 1930/40 or after. As you will see, they have become very Westernised. No doubt the tourist trade is an influence here. More important, they are essentially representational, although in a stylised fashion; and asymmetry makes its first appearance.

The two Pueblo designs were included as a check for designs E and F since they are traditional patterns of a so-called 'primitive' type, but rather more developed within their own style. The obsolete recapitulation theory of child-development,

[1] Paper delivered to Section J (Psychology) on September 8, 1959, at the York Meeting of the British Association.

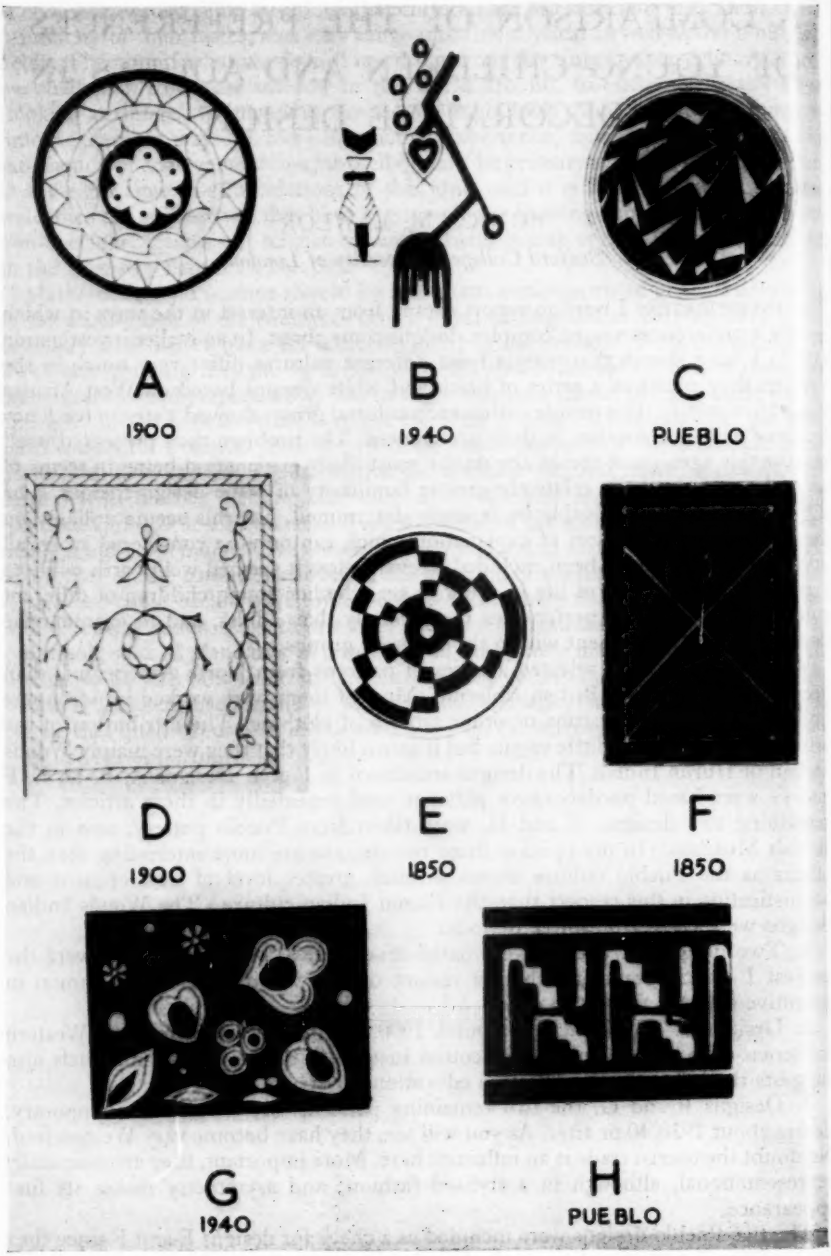

FIG. 1. North American Indian designs used in the investigation (these were shown to the subjects without the dates or identification letters)

as well as the much more popular theories of Jungian psychology, both suggest that there is an essential mental affinity between children and primitive peoples because they draw and paint alike. It seemed plausible that if there were anything in this theory, this would be reflected in what children prefer as well as what they produce (especially since the primitive qualities of the latter could as easily be the result of ineptitude as of actual preference).

The series of eight designs therefore contains four primitive or traditional decorative designs used in indigenous North American societies; two fairly recent designs from the same source; and two dating about fifty years back when acculturation was a national policy in all North America. The materials themselves show an interesting change, one which I think might be explained in the light of findings discussed later in the paper. Since I presented the designs, originally coloured, in a black-and-white form in order to focus attention on the pattern forms, an important element was omitted. The colours no less than the design varied with the period, but a separate investigation which I have no space to describe gave very similar results to those I am about to discuss.

The designs used in the experiment were made up from sections of pattern copied from the original articles. The final form was a series of more or less complete patterns in black and white on 8 in. by 7 in. paper, and the majority of the subjects were shown these originals. A few of the later ones were given photographic reproductions of these, either the same size as the originals or in a miniature 2 in. by 3 in. form. The preferences did not seem to be changed by this mode of presentation. Since the actual form of the patterns used was derivative, the materials cannot be regarded as products of creative art but rather the kind of rearrangement of decorative motifs which would occur in the use of a traditional pattern by a craftsman rather than an artist. I make no claim to be dealing with the kind of aesthetic preference involved in the response to great art, but only with the kind that makes us choose one wallpaper rather than another, or this curtain material rather than that. The relation between the two is not a question for this paper.

So much for the materials. The method of obtaining the preferences was simple. The subjects were shown all eight black-and-white designs and asked to say which one they liked best and which one they liked least. Some of the more sophisticated subjects immediately protested that they did not like any of them, but could usually make a choice when asked which they disliked least and which they loathed most. As in most experiments of this kind, the resulting judgment is relative, there is no record of the absolute scale of liking/disliking of the whole series. The problem created in this way is of only limited practical significance, since unless we are gifted enough to create the things we wish to live with, or wealthy enough to have them made to precise specifications, we all have to choose within the limits of what is available in acquiring our household gods.

The people who were asked to make the choices must be described next. As I said earlier, the main object of the experiment was to obtain the preferences of young children and compare them with those of adults. With this in view, 249 five- or six-year-old children in three church schools and one L.C.C. primary school in South London were shown the designs and asked to say which they liked best and which least. They did this readily enough and with apparent interest and firmness. A few had trouble with the dislike choice, and if they did not seem to get the point I did not press for the second choice; but only five of them did not make the dislike choice. I tried slightly younger children, but at four years old, though willing to co-operate, they did not seem interested in the designs; they would just point absently in the direction of the designs while smiling hopefully at me. Of the 249 children, about 80 had been at school for a year, but for the majority it was the beginning of their first term. The area in question is a working-class district, settled and reasonably prosperous, the majority of people living in it being either

semi-skilled or skilled manual workers with a fair sprinkling of clerical workers. There were roughly the same number of boys and girls in this group.

The designs were then shown to 279 adults (105 men and 174 women). These were mainly from the London area, but the majority of them were professional people or students with grammar school and/or university education. They consisted of a small group of teachers (including the class teachers of all the children tested), some 54 men and women who came to a display in the Psychology Department at Bedford College (mainly students and university teachers), 43 personnel officers and psychologists, about 25 doctors, 49 nurses, 29 medical students, 8 students from a technical college, and 66 people, patients and their friends and relations, from the general wards of a London teaching hospital. Only this last group came from roughly the same socio-economic level as the children.[1]

The method of collecting the adults' choices varied a little. The majority were collected by myself and Miss Doniach, and two colleagues collected another forty between them. The only remaining subjects to be considered are twenty girls between the ages of twelve and seventeen from an independent secondary school in the Midlands. Another of my students collected these preferences for me when a check seemed called for in the interpretation of the results.

So much for the materials, the method and the subjects. I can now give you the results. The first point to establish is that the distribution of the choices (with all groups, young and old, taken together) amply confirms the previous finding that people from the same culture are markedly similar in their preferences. The extent of group agreement in this case is such as would be expected by chance less than once in 10,000 times ($\chi^2 = 168 \cdot 33$). In terms of the designs, this meant that designs A, B and G accounted for nearly three-quarters of the preferences. More than one-quarter (nearly one-third) preferred G to any other design. On the other hand, F and H together accounted for only about 10 per cent of all the preferences. Thus the contemporary designs are clearly preferred to the primitive. This general statement, however, obscures the more interesting aspects of the findings.

In order to answer the original question about the differences between the preferences of children and adults it is first of all necessary to note a sex difference in preference. There is a substantial difference at all age-levels between the males and females. It is in fact larger and more consistent than any other difference. Because of that, it became necessary to separate the results from the two sexes before comparing children with adults. When the sexes are separated and the two relevant comparisons are made, we find that there is no significant difference between the preference choices of the five- and six-year-old boys and the men.[2] The results from both the children and the adults, taken separately, show a high degree of internal agreement, and the extent of agreement between the men and the boys seems therefore to reflect a real common preference pattern. The female group shows largely similar results. The agreement within the separate groups is equally good. If we compare all the five- and six-year-old girls with all the women, however, there is a difference in preference. The girls, on the whole, like designs G and D while the women like G and C. But now, if we separate the adult women into two groups, one which I will call for convenience the general population sample (provided by the forty-seven female patients and their female friends and relations), the other which I will call the professional group (nurses, students, doctors, teachers, etc.), we find that the liking for design C is almost wholly confined to this

[1] I should like to take this opportunity of recording my debt to the late Miss Vera Doniach, one of our students, who collected the preferences from this group as well as about 100 of the remaining subjects. Without her help while she was in hospital it would have been impossible to get such a complete and varied sample.

[2] The chi-square test was used to test all differences reported—differences reported 'not significant' had P values above the 5 per cent level, while 'significant' difference had P levels, in all but one case, below the 1 per cent level.

second, professional group. The first group, the random sample, display a remarkable degree of internal agreement (nearly three out of every five prefer design G to any other), but they barely differ in preference from the girls who have just come to school, and there is no significant difference between their preferences and those of five- and six-year-old girls who have been at school for a year, nor between either of these groups and the small group of older girls.

We thus find *not* that children prefer more primitive designs but that they like much the same patterns as adults, the boys liking what the men like, and the girls liking what the women like. The only group who tend to like the more primitive designs are the professional women who like the Pueblo design C.

These findings lead to the conclusion that there is little point in carrying the comparative study of cultures down to an early age-level in the hope of finding culture-free preferences (though for other purposes the comparison would still be interesting) since we find that as soon as a child will express any choice among designs of this kind he prefers not only what the adults of his culture prefer but has a strong tendency to prefer what adults of the same sex prefer.

That the sex difference found in the children is much the same both in extent and kind as that seen in adults seems to me important. It must however be borne in mind that there is much overlap in preference between the male and female groups—a measure of agreement which will cover some three-quarters of all choices made. In their reaction to designs A, C, F and H, no difference between the sexes is apparent. With the remaining designs we can say that while, among the children, two boys will choose design B for every one girl who does so, two girls will choose design G for every boy who does so. Both these designs are, however, reasonably popular with both groups. The other two designs, D and E, give a clearer distinction; for every girl that chooses E, seven boys will choose it, and for every boy who chooses D, seven girls will choose it.

When we come to compare the adult groups much the same holds as for the younger groups, with two exceptions: first, that less agreement is shown within the group of adult men than within the group of boys; second, that the professional women resemble the men more than do the women from the general population sample. This latter fact comes about because the professional women are less attracted to the representational design G and show more liking for designs B and C, but particularly C. But the difference between the sexes is still a significant one.

The main difference is that the girls and the women tend to prefer a more representational design while the boys and the men show a greater readiness to choose a more abstract or formal design. It is also possible to regard both B and E as rather bolder in treatment than G and D; there are fewer fine lines and fewer frills.

Looking at the designs (see Fig. 1), one can see that any explanation in terms of classical psycho-analytic symbolism such as McElroy (1954) or Jahoda (1956) suggests simply does not fit the data. Put briefly, their hypothesis is that boys will tend to like female symbols (anything curved or even roughly circular) and girls will like masculine symbols (anything square or pointed): if the difference which they found in the preference for pairs of line figures had the very simple symbolic meaning for the subjects which they suggest, then it is hard to see why this does not hold for more complex figures. The explanation would seem to be that, given a choice between two line drawings of no interest, the child will invest them with symbolic meaning, but this symbolic meaning is not the most important thing in appreciating designs that have greater intrinsic interest. It will be obvious that most of the designs I used are mixed symbols, but that some contain more curves and others more angles and that the sex difference does not follow the symbol difference in the predicted direction.

To regard the more complex material as obscuring the basic symbols leaves one

without any explanation of the remarkable fact that the sex difference found here is at least as great as that reported by McElroy and Jahoda although the material has not been reduced to a series of curves and angles.

Thus the difference in preference between males and females presents a complex problem for interpretation. If one ignores for the moment the question of symbolism and attempts an explanation in terms of different levels of familiarity or social experience, further problems present themselves. At five or six, small boys have usually passed most of their time in a material environment which differs little from that of small girls, and in addition they have lived in a predominantly female world. The dynamics of the difference are clearly internal. The material as opposed to the emotional environment cannot play much of a part in determining the differences, though it may explain the similarities. It seems very unlikely that in the pre-school years any direct training is given in the matter of decorative design. We can say vaguely that 'social pressures and expectations' may have been at work, but precisely what they are and how they work to bring about well-established sex differences in preference for designs by the age of five must be regarded as a challenge to further research.

Returning now to my main theme, I must draw your attention once again to the overall agreement of all groups, old and young, male and female, disregarding for the moment the differences I have just discussed. Something over 20 per cent of all the groups choose design G as the one they like best. It is chosen by 25 per cent of both boys and girls who have just started school. After the first year at school it is chosen by 36 per cent of the girls and 29 per cent of the boys. It is chosen by 19 per cent of the adult men, 28 per cent of the professional women and 59 per cent of the general-population sample of women. This shows something of the measure of general agreement which exists in spite of considerable differences.

The essentially social character of this agreement is suggested by the fact that women at all age-levels—even at five years old—show a greater tendency than the men to choose alike, a tendency that probably reflects some greater interest in design and pattern among them, more tendency perhaps to discuss it, to air their views and to share them. Among the more highly educated women this attention to design becomes, I imagine, more conscious, more attentive and more deliberate; probably it reflects a greater attention to the materials and less to the social context in which they occur. At any rate it suggests that active attention is involved rather than habit. This development of active interest is probably less common in men for a variety of reasons, the most important of which is likely to be the absence of any direct social sanction for, or expectation of, such an interest.

If I am correct in my suggestion that the differences in preference between children and adults have been much exaggerated, then we have to recognise the fact that in the early years of life when so much is learnt, the accidentals of culture are also absorbed. By the time a child is five he has acquired along with language, locomotion, and other essential equipment, not only the manners and modes of behaviour he is deliberately taught, but the tastes and preferences to which he is exposed more or less haphazard. The critical importance of these formative years for personality and character development is now generally recognised and there is plenty of evidence that important features of personality have been established by this age. I do not wish to suggest—it would be foolish to do so—that the stable entity of five-year-old character is immutable, but what I would suggest is that the changes which take place during the school years and in later life come about in a rather different way from the earlier development; they rest much more on conscious appraisal, conscious effort (whether at understanding or imitation), conscious response and conscious decision. The patterns first laid down are in a sense learnt, but much of this learning can best be described either in terms of the psychoanalytic concept of introjection of models, or of casual conditioning or habituation.

Because so much is unwittingly absorbed, and because it comes first, it has a great resistance to change—a resistance too frequently demonstrated to require any further demonstration here.

We can, it seems to me, explain this general degree of agreement between all the subjects used here by considering their common experience. The culture in which we live inevitably provides us with a greater measure of familiarity with some styles, in furniture, decoration, architecture, clothes and so forth, rather than others. This familiarity is not so much a matter of monotonous repetition as of continuous variation among a limited number of themes. We respond to the common aspects of these experiences, and any new stimulus will be familiar in so far as it contains these aspects and strange in so far as it does not. The mental effort involved in appreciating the unfamiliar will be greater since it will involve some effort to absorb and understand its important elements. Having made this effort, we may still not like it; but this dislike will be qualitatively different from the dislike which arises from an almost automatic dismissal of it just because it is unfamiliar. Probably the greatest difference between sophisticated and unsophisticated taste lies in this—that in the person with sophisticated taste the automatic preference system, laid down in early childhood, has come under review. Because of differences of interest we do not all pay attention to the same things. In our 'unreviewed' systems of preference rests the stability of choice which gives rise to the strong cultural norm which I have described here with special reference to the field of design and decoration.

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THE ORIGIN OF 'THE ORIGIN'[1]

AS DISCERNED FROM CHARLES DARWIN'S NOTEBOOKS AND HIS ANNOTATIONS IN THE BOOKS HE READ BETWEEN 1837 AND 1842

by

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IT SEEMS strange that there is anything that needs to be said on this subject, concerning such a relatively recent event, apparently well documented in the voluminous sources in print, and indeed described by the author himself in his *Autobiography* now before us complete as edited by his granddaughter, Lady Barlow. There are, however, odd inconsistencies between the *Autobiography* and certain remarks scattered in the correspondence; moreover, there is still, as one sees with great surprise, a considerable quantity of unpublished holograph material which bears on this subject to be found in the Darwin papers in Cambridge University Library (to which they were presented jointly by the Family and the Pilgrim Trust in 1942) and in the margins and on the fly leaves of books from Darwin's library housed in his old study at Down House on permanent loan from the Professor of Botany at Cambridge (to the holder of which office Francis Darwin bequeathed Charles Darwin's working library in 1908).

The Centenary's spate of publication has thrown up extensive and often valuable studies by a number of people. These are for the most part revaluations of existing published material taken in a wide historical context but not involving any extensive study of primary unpublished source material. Such a work is *Darwin's Century —Evolution and the Men who discovered it*, by the American anthropologist Dr. Loren Eiseley. Another study which has made partial (in two senses) use of the unpublished Cambridge University Darwin material is the recent *Darwin and the Darwinian Revolution*, by Miss Gertrude Himmelfarb, a historian who has from internal evidence little direct knowledge of biology or appreciation of the difficulties of the subject. More recently still (since the delivery of this talk) Prof. Darlington's pamphlet on 'Darwin's place in history', in which he reminds us of the hitherto unconsidered claims of W. Lawrence and J. C. Prichard, has been published. The claims of Lamarck as evolutionist have also been put forward by Prof. Graham Cannon with a somewhat partial advocacy in his *Lamarck and Modern Genetics*. Dr. Eiseley, after his demonstration of the influence the reading of Lyell's *Principles of Geology: being an inquiry how far the former changes of the earth's surface are referable to causes now in operation* had on the development of Charles Darwin's ideas, has recently drawn attention to the writings of Edward Blyth (1810-73)—reprinting the relevant papers in full—in the *Proc. Amer. Phil. Soc.* (1959), **103**, 94–158. I quote from Professor Dobzhansky (1959), *American Naturalist* concerning this latter work as follows: 'Eiseley argues not only that the basic tenets of the theory of natural selection were stated by Blyth much earlier than by Darwin, but also that Darwin was familiar with Blyth's idea, made use of it in his theories, and yet failed to acknowledge his obligation to Blyth.' Miss Himmelfarb, alternating between fascination and irritation with her subject, while clearly admiring and showing affection for him as a person, nevertheless makes frequent recourse to incomplete and out of context quotation to help

[1] Paper delivered to Section D (Zoology) on September 9, 1959, at the York Meeting of the British Association.

achieve her aim of undermining the towering edifice of Natural Selection by a diligent picking away at what she supposes to be the foundations. As an example interested readers might care to relate her quotation on p. 92 of Huxley's—'a vast accumulation of useless manuscript'—to its full context in Huxley's *Darwiniana*, p. 271.

In these circumstances it is imperative to establish as accurate a chronology as possible of the development of Darwin's ideas from his own largely unpublished writings, and, equally important, to establish how much of his ideas were essentially complete in his mind before he read these authors whose clothes he has been supposed to have stolen for his selfish adornment. The immediate and overwhelming success of the *Origin* had two important consequences: first it so altered the topography of the biological sciences that it was thereafter difficult to evaluate as a work of scholarship, a task not made any the easier by the complete omission of all references to preceding workers in the field, and second the book sold so well that its publisher John Murray urged on Darwin, against his own judgment, its retention in more or less the same format, with the consequence that the opportunity was missed for the publication of an earlier, more extensive, version of which a substantial part still exists in manuscript amongst the Cambridge Darwin papers. Prof. R. C. Stauffer (*Science* (1959), **130**, 1449–52), who is engaged on a complete publication of this material, assures me that it has a full range of scholarly apparatus appropriate for the work. The *Origin* as we know it is thus a summary and digest of this larger work set as it were in a mould because of the need to produce such a commercially gratifying series of editions, in each of which, Darwin strives with manifest care to meet criticisms of detail while leaving the scale and format of the work as nearly as possible unchanged. The first edition of the *Origin* has thus come to be thought of as the beginning rather than as the culmination of more than twenty-one years of reading, research and anxious thought on the part of its author.

Let us see what is to be found in the notebooks, the marginal annotations and the reading lists which survive for the formative period 1837 to 1842. Their study permits the tentative conclusion that Darwin did not, as some commentators assume, become a convert to a theory of transmutation while on the voyage of the *Beagle*. It was after his return, during the first few months spent unpacking and sorting his collections, collating them with his field notes, and in writing up an extended version of his diary of the voyage that he seems to have formulated his theory essentially complete from the creative moment of imaginative insight. This moment cannot be later than March 1837, when the fifth edition of Lyell's *Geology* was published, for his marginal annotations in the copy at Down House precede in date the first of the 'Transmutation' notebooks begun the following July. The theory was clear in his mind from the outset, and was sufficiently compelling for Darwin to undertake the labour of accumulating relevant facts wherever they were to be found. This process proved so lengthy, both in fact and in retrospect, that Darwin later claimed that his idea arose from a strict application to his massively detailed evidence of 'Baconian' methods of induction. He seems to have derived this concept from a critical reading of Whewell's *History of the Inductive Sciences* shortly after its first publication in 1837. This claim is an egregious example of self deception. In the marginal annotations to Lyell's fifth edition he writes as a transmutationist arguing for what he calls 'my theory' against the cogently argued review of evidence surveyed with Lyell's customary forensic skill in a contrary sense. As will be seen 'my theory' of those early days contained in essence his later and fully documented presentations of his theory. It had, moreover, the impetus to carry him through long years of 'endless oscillations of doubt and difficulty' of which he wrote to George Bentham on June 19, 1863 (*L. & L.*, III, 26). Darwin became the undoubted world figure he is because he

was not only a superb observer of nature in the field and a meticulous and tireless collector and collator of the detailed observations of others in natural history, but also he had that rarer spark of genius which led to this creative flash of intuitive insight. He was a genius who took infinite pains—and twenty-two years—so that his theory would finally appear growing as a mature tree in the rich well-tilled soil of fact which sustains it to this day. His mature presentation in which Darwin 'not only hit upon a novel idea but found a means to outflank the principal weakness of his book' . . . enabled 'the doctrine of evolution to stand free of many dubious associations and stale perplexities', as Donald Fleming writes (*J. Hist. Ideas*, (1959), **20,** 437), and contributed largely to the success of his theory. A more slender basis of fact and a less skilful presentation and the theory would have remained unknown and unregarded like the theories of his admitted predecessors, until the triumph of the *Origin* made their prior existence worthy of notice. As Fleming concludes, 'The centennial of the "Origin" is a greater event and Darwin a greater man than many of the celebrators appear to think'.

Darwin's Journal—'a little diary which I have always kept (*L. & L.*, I, 80)'—is for the first time available complete, edited and annotated by Sir Gavin de Beer, from the transcript preserved at Cambridge. Under the entries for 1837 there is the well-known passage: 'In July opened first notebook on "Transmutation of Species"—Had been greatly struck from about month of previous March on character of S. American fossils—& species on Galapagos Archipelago. These facts origin (especially latter) of all my views.' February 1838 has the entry: 'Also speculated much about "Existence of Species" & read more than usual.' May 1 he was 'Unwell, working at Geolog: as named and "species".' Early in June there was 'some little species theory' and in the latter half of July he wrote 'Very idle at Shrewsbury, some notes from my father. Opened notebook connected with metaphysical enquiries' ('Expression' book 'M' begun July 15, 1838). In August Charles 'Read a good deal of various amusing books and paid some attention to Metaphysical subjects'. The entry for September 14 reads: 'Frittered these foregoing days away on working on Transmutation theories & correcting Glen Roy. Began Crater of Elevation theory.' September was spent reading a good deal on many subjects. On October 25 he 'Went to Windsor for two days rest, glorious weather, delightful'. The entry 'November 11th Sunday The day of days!' commemorates the acceptance by Emma Wedgewood of his proposal of marriage. House-hunting and moving into 12 Upper Gower Street took up most of the time until marriage on January 29, 1839. Back in London 'February 5th Began German'. 'A little species work' occupied the end of February and the first week in March and 'some reading connected with Species' was done while on a visit to his father-in-law at Maer during April and May. A little more work on species was achieved, though interrupted by illness, during July and August. In March 1841 species theory papers were sorted. Then follows an interruption owing to the writing of the Coral work until May 18, 1842, when Charles 'Went to Maer' and from thence to Shrewsbury. On June 15 'during my stay at Maer and Shrewsbury (five years after commencement) wrote pencil sketch of my Species theory'. The first of all versions of the *Origin* has been shaped. The second version is referred to under February 13, 1844, where the entry reads: 'In intervals & previously slowly enlarged and improved pencil sketch in 35 pages (written in Mid-summer of 1842) of Species theory.' It is this draft that Charles considered so important that, concerned to ensure its publication 'in case of my sudden death', he wrote a letter (*L. & L.*, II, 16 (July 5, 1844)) to his wife in which may be read the following:

I wish that my sketch be given to some competent person with this sum (£400) to induce him to take trouble in its improvement and enlargement. I give him all my books on Natural History, which are either scored or have references at the end of the pages,

begging him carefully to look over and consider such passages . . . I also request that you will hand over (to) him all those scraps roughly divided in eight or ten brown paper portfolios. The scraps, with copied quotations from various works, are those which may aid my editor . . . With respect to editors, Mr. Lyell would be the best if he would undertake it; I believe he would find the work pleasant, and he would learn some facts new to him.

The importance of this letter to Darwin can be inferred from the later textual alterations made from time to time when an extra hundred pounds is offered and further suggestions are made concerning possible editors. With publication of the *Origin* the provisions of the letter became redundant but the books and notes, though inconveniently dispersed between Down House and Cambridge, are still available for study.

The notebooks are foremost in importance though considerably mutilated when material was abstracted for the third most extensive draft of the *Origin*. One or two of the missing notebook pages have been identified amongst the Darwin papers by Prof. Stauffer, Mr. Gautrey and myself but there is a great deal more to be done. There are seven pocket-books at Cambridge. The first, 'A', concerns geological matters, four books labelled 'B' to 'E' are concerned with 'Transmutation' and the last two 'M' and 'N' are labelled by Darwin 'Expression'. The first Transmutation book 'B' is headed 'Zoonomia' (*L. & L.*, II, 5. footnote †) and there seems little doubt that the notes relate to the first post *Beagle* reading of his Grandfather Erasmus's classic work. Page 59 of this notebook carries a reference to p. 379 of the third volume of Lyell's *Principles* in the fifth edition. There is thus solid ground for supposing he had read the two preceding volumes before July 1837, when the notebook was begun. Page 235 of this notebook is dated January 1838. 'C', 'written between the beginning of February 1838 & July 1838' according to Darwin's annotation on the flyleaf, carries on the last few pages two book lists, one headed in a contemporary hand 'Books examined: with ref: to Species' the other headed 'Books to be read'. Two pages have been cut out in the middle of the list of books read, but this mutilation occurred before the list was written, since the slightly later copy of this reading list (Darwin Papers, 119) reproduces the list almost exactly. This later copy was used until 1851; the 'books read' list is here headed 'These books have been read since I thought of my Transmutation theory'. This copy seems to have been made in the early days at Down House, it is not in Emma's hand and was possibly done by one of Charles's sisters. The book entries are copied from 'C', thereafter all entries are in Charles's hand. Notebooks 'D' and 'M' were begun on the same day, July 15, 1838, and apparently both finished on the same day, October 2, 1838. 'D' bears in pencil on the inner cover a later note, 'Towards close I first thought of selection owing to struggle'. The first two pages of 'E' have been cut out, but p. 4 bears the date October 4; the book was finished July 10, 1839. 'M' bears on its inner cover, 'This book full of Metaphysics and Morals & Speculation on Expression'; the last 'N' begun October 2, 1838, has the note, 'Metaphysics and Expression', and is still unfinished.

The process of mutilation may be followed from Charles's notes on the inner covers. 'B' has 'all useful Pages cut out December 7 1856' and 'looked through April 21 1873'; 'C', 'all good references selected December 13 1856'; 'D', 'all selected December 14 1856', and 'E' has no note, though pages have been cut out. 'M' was 'selected December 16 1856' and 'N' has been promoted from the Metaphysical limbo for it bears the note, 'Selected (for Species Theory) December 16 1856'. 'Looked through and all other Books May 1873'. These notebooks were thus gone through twice with care after the drafts of 1842 and 1844 were compiled, and even though in their present state they represent what Charles Darwin thought at the time to be of insufficient importance to be cut out and used,

to the reader today they have an abiding fascination. As a sample of what they show I reproduce below (with the kind permission of the Darwin family) a page of the reading list from 'C', which covers the reading done between August 1838 and early October in transcript and in a separate column the references to the works read in the respective notebooks. As stated in his *Autobiography* (N. Barlow edition, p. 120), Darwin read Malthus in October 1838. It is gratifying to find confirmation not only from the reading lists but also from the notebooks.

A Page of the Reading List from Notebook 'C'

~~Rays Wisdom of~~	Nothing	
Lisiansky's Voyage round world.	1803–6	
Lyell's Elements of Geology		
Gibbons life of himself		
Humes do, with correspond. with Rousseau		
Miss Martineau How to observe		"M" pp. 75–77
Mayo Philosophy of Art of Living		'M" several pages
Several of Walter Savage Landor's Imaginary Conversations—very poor		
Sir T. Browne's Religio Medici.		"M" page 126
Lyell Book III. There are many marginal notes.		
Mitchell's Australia.		"D". 132
Walter Scott's Life 1 & 2d & 3d Volumes		"M" p. 129 The next page is dated Sept 3.
Abercrombie on the Intellectual Powers		
Hunter's Animal Economy edited by Owen. read several papers—all that bear on any of my subjects.		"D" pp. 158–161
Elie de Beaumont's IV Vol. of Memoirs on Geolog of France = ~~on Etna almost reread the previous volume~~ & C. Prevost on l'Ile Julie		
Waterton's Essays on Natural History	Octob. 2d	"N" pp 1–4
Transaction of Royal Irish Academy	——do.	"D" p. 164.
Lavater's Physiognomy	Octob. 3d	"D" pp 164/5.
Malthus on Population.		"D" pp. 166–179. "E" pp. 1–17.
W. Earl's Eastern Seas.	Octob. 12th	"E" p. 18.

As can be seen, reading lists, notebooks and marginal annotations can be woven into a consistent fabric. I have in the time at my disposal been able to make only a fragmentary survey which concentrates on some of the authors rightly regarded as the most significant. It is now time to review my main conclusions.

Much is made by commentators of the influence of Charles Darwin's reading while he was a student with his brother Erasmus at Edinburgh. It is perhaps not generally realised that he was only a boy of 16 to 18 during these formative years when he came under the influence of Dr. Grant, who 'burst forth in high admiration of Lamarck and his views on Evolution. I listened in silent astonishment, and as far as I can judge without any effect on my mind' (*Autobiography*, N. Barlow edition, p. 49). Grant's influence is mentioned as early as February 16, 1838, in Whewell's Anniversary address to the Geological Society of London where, speaking of Charles Darwin, he says Darwin 'studied under Grant at Edinburgh, Henslow and Sedgwick at Cambridge'. Grant's influence, no doubt can be traced in 'Notes on Lamarck's arrangement of Les Animals (*sic*) sans Vertebra (*sic*)'

which survive amongst documents from his Edinburgh days. When Lamarck's views confronted him as set out in the second volume of Lyell's *Principles* (first edition), the surviving volume, as we shall see, affords mute testimony that they did not induce the slightest reaction on Charles's part.

Charles Lyell, who was nearly twelve years senior to Charles Darwin, published the first volume in January 1830 in ample time for Prof. Henslow to advise Darwin to take it with him on the *Beagle*, with the warning 'on no account to accept the views therein advocated'. (*Autobiography*, p. 101). This volume at Down is fully annotated. The second volume was to be concerned with 'the change in organic life, which I intend to be more generally entertaining than the inorganic, and more new . . .' (Lyell: letter of June 14, 1830). Already by December 5, 1829, he had spoken of it as 'in a manner written, but will require recasting'. Later in 1830 Lyell wrote speaking of Etna shells . . . 'they lived on a moderate computation 100,000 years ago, and after so many generations are quite unchanged in form. It must therefore have required a good time for Ourang-outangs to become men on Lamarckian principles.' This second volume was not published until January 1832, and Darwin's copy is signed and dated 'M:Video. Novem 1832' (Montevideo). Here Lyell reviews Lamarck's ideas and surveys the whole field of biology to demonstrate 'The reality of species in nature'. His evidence is presented and summarised as if he were writing a legal opinion, for Lyell was trained in the Special Pleader's office, but did not practice because of weak eyesight. Lyell's personal views at this time were in favour of transmutation and thus did not coincide with the conclusions in his published writings. This fact is clear from the letters he wrote to his friends and may account in some measure for the delay in the publication of volume two. This ambiguous situation was first pointed out by T. H. Huxley (*L. & L.*, II, 191) and it has recently been commented on by Prof. Eiseley (*Darwin's Century*, p. 102; Sir Gavin de Beer (1959), p. 33) and Prof. Graham Cannon (*Lamarck and Modern Genetics*, pp. 19–22), who further justly charges Lyell with a partial misunderstanding of Lamarck while nevertheless conceding that Lyell in all other respects gives 'an admirable and concise account' of Lamarck's evolutionary views. Charles studied this volume with care while on the voyage, for he makes many references to it in his correspondence, but the copy is almost without a note and some of the index pages are not even cut. There is the single word 'Galapagos' in the margin near to an observation on the structure of a fringing reef, but not the slightest response seems to have been elicited by Lyell's masterly arguments that species were real, i.e., unvarying and therefore could not have arisen by transmutation.

Lyell's third and final volume was published in May 1833 and Charles wrote from Valparaiso on July 24, 1834, to Prof. Henslow: 'I had deferred reading his third volume till my return: you may guess how much pleasure it gave me; some of his woodcuts came so exactly into play that I have only to refer to them instead of redrawing similar ones.'

It was in September 1835 that the long-anticipated visit to the Galapagos Islands was made. In July 1835 Charles wrote to his sister Caroline: 'I am very anxious for the Galapagos Islands—I think both the Geology and Zoology cannot fail to be very interesting.' Before the *Beagle* left South America a large cargo of specimens was sent to Henslow. For space was at a premium on board. Captain P. G. King (one of Darwin's shipmates) in later life wrote that the space available to Charles was 'certainly not exceeding 9 feet long by 5 broad and 6 deep. Within this space he worked by day at his microscopes and journals and slept by night in a cot suspended within 2 feet of the deck above his head . . . half this space overhung the vessels' stern post.' It seems unlikely that Charles would have the space to examine the extensive Galápagos collections, or indeed the time, for the *Beagle* visited Tahiti, New Zealand, Australia, Tasmania, the Keeling Islands,

and Mauritius before reaching the Cape of Good Hope early in June 1836. It was on the latter part of the voyage that Captain FitzRoy and Darwin wrote their joint pamphlet entitled, 'A Letter containing Remarks on the Moral State of Tahiti, New Zealand &c.', which was published in the September issue of the *South African Christian Recorder* in which both authors advocate individual and Government support for the missionaries in the Pacific.

Specimens had all the while been accumulating at Cambridge in the custody of Prof. Henslow and it was to Cambridge that Charles repaired once he had revisited his family after landing at Falmouth on October 2, 1836. He soon resumed his acquaintanceship with Charles Lyell for, as early as October 26, we find Lyell inviting Richard Owen to meet Charles 'at an early tea party at 8 o'clock. Among others you will meet Mr. Charles Darwin, whom I believe you have seen, just returned from South America, where he has laboured for Zoologists as well as for hammer-bearers.' I am grateful to Sir Gavin de Beer for pointing out that the two had most probably first met at Prof. Henslow's in June 1831—in an earlier account I had suggested Charles Darwin and Lyell did not meet until 1836.

Charles's copy of the fifth edition of Lyell's *Principles*, set up in four duodecimo volumes, is at Down. The second volume ends after three chapters reviewing the evidence concerning the reality of species in nature.

Thus there was available to Charles (ever economical in the use of paper) a half sheet and the facing empty flysheet for annotations. It is here that we see abundant evidence that Charles Darwin is by now a convinced believer in the transmutation of species. The fifth edition was published in March 1837, which collates well with his personal notebook. The specimens had been unpacked at Cambridge, he was writing up his field notes, he had met and possibly argued with Charles Lyell and for the first time read and reacted sharply to the latter's firm public advocacy of the fixity of species in nature. The variations which occurred in nature were in this survey, so to speak, like slight perturbations of a pendulum which under the natural restoring force of gravity returns after a while to its former state of equilibrium. For Charles a disturbance of equilibrium must be maintained and increased for transmutation to become possible. It is now time to look at these annotations in detail. I give the Lyell text in full with Darwin's annotations quoted within brackets.

> 1st. That there is a capacity in all species to accommodate themselves, to a certain extent, to a change of external circumstances, this extent varying greatly according to the species.
>
> 2ndly. When the change of situation which they can endure is great (or small), it is usually attended by some modifications of the form, colour, size, structure, or other particulars; but the mutations thus superinduced are governed by constant laws, and the capability of so varying forms part of the permanent specific character. (There is a line in the margin to draw attention to this last clause, and the comment 'with respect to changes superinduced in short period'.)
>
> 3rdly. Some acquired peculiarities of form, structure, and instinct, are transmissible to the offspring (with no tendency to go back); but these consist of such qualities and attributes only as are intimately related to the normal wants and propensities of the species.
>
> 4thly. The entire variation from the original type, which any given kind of change can produce, may usually be effected in a brief period of time, after which no farther deviation can be obtained by continuing to alter the circumstances, though ever so gradually—indefinite divergence, either in the way of improvement or deterioration (Darwin's underlining, as note on the facing fly sheet 'without reference to either, but simple change' refers to this underlining), being prevented, and the least possible excess beyond defined limits being fatal to the existence of the individual. ('if this were *true* adios *theory*') is written in the margin opposite the underlining.

5thly. The intermixture of distinct species is guarded against by the aversion of the individuals composing them to sexual union, or by the sterility of the mule offspring. It does not appear that true hybrid races have ever been perpetuated for several generations, even by the assistance of man; for the cases usually cited relate to the crossing of mules with individuals of pure species, and not to the intermixture of hybrid with hybrid.

6thly. From the above considerations, it appears that species have a real existence in nature, and that each is endowed, at the time of its creation, with the attributes and organization by which it is now distinguished.

Among the notes on the facing flysheet there is a comment on paragraph 5. 'The great difficult (*sic*) appears, that though some animals long domesticated change not indefinite (Do we know this) but most domesticated animals are hereditary monsters. Yet we should have expected some race which would have showed a slight repugnance to breed with our animals.' Then follows further comment upon paragraph 2: 'The changes apparently being rapidly* superinduced in domestic animals. N.B. The very character of species is character being hereditary, & as we know we can find forms not hereditary some that are we might expect gradation.' This note has the comment on the facing page: '*Against 2d Excellent argument sheep do not get big tails in Africa or cattle long hair or Cow hump on back, a dog-like form in Australia . . . . . (a few words illegible) yet whole breed truly. So it must be effect of country yet existing or else nature would have bred back.'

'Now if in course of ages (having shown time is requisite) offspring differed as much from Indian Cattle & long horned do. (Buffalo near.) as these do now from common stock then would they perish.'

The temptation to make further quotation must be resisted but perhaps space can be found for the following comment elicited by Lyell's question (Vol. II, p. 374), 'Why have the majority of existing creatures remained stationary throughout this long succession of epochs, while others have made such prodigious advances?' —which takes up the whole of the lower margin of the page—'Because there were localities fitted for simplest animals as well as the most complex. Therefore some remained simple. if not created. The incidental good which one race performs to other proves adaptation in Universe.' On p. 386 of the same volume, where the test for a species is discussed, Charles writes lengthways in the margin, 'In Mammalia we must stick to one rule—let fertility be test—'. On p. 119 of Volume III, after Lyell's concluding remarks to Book III, we have this footnote from Charles: 'will the theory do—form acquired but not unacquired ∴ change extermination.'

The three essential minimal hypotheses for present-day Darwinian theory are: the occurrence of variation in nature; the selection of more favoured variants in a particular habitat; and the preservation of these variants intact for hereditary transmission to their progeny without dilution by a process of blending inheritance. The responses by Darwin to the passages quoted above show that as early as March 1837 his grasp of the essentials of his theory, though probably intuitive, was complete. To pick up these particular points in Lyell's 'opinion' for comment can be interpreted in no other way. Darwin is plainly unwilling to accept any limitation on the ultimate extent of any change which might result from the selection process as his comment 'if this were *true* adios *theory*' shows. He is not accepting or even contemplating the implications of blending inheritance at this date or he would not have added the gloss 'with no tendency to go back' and the note 'the very character is character being hereditary'. Darwin in his drafts of 1842 and 1844 was to sophisticate this almost mathematical intuition as the weight of accumulated evidence and the caution bred of the advice from friends led him to weaken his argument. It is notorious that this process continued further in the successive editions of the *Origin*.

Lyell's numerous references include Lamarck, Lawrence and Prichard; it is of the last that Lyell speaks especially highly for his survey of the geographical distribution of animals. These references were not followed up immediately, but the travels of von Buch noted on the end flyleaf of Lyell (Vol. II) were studied straight away and numerous references are made to this work in notebook 'B', which has just been published with introduction and notes tracing the references by Sir Gavin de Beer (1960). Charles was much preoccupied with his Galápagos observations and writes in 'B', p. 98, with even more than the usual illegibility as follows, 'This question if creative power acted at Galapagos it so acted that birds with plumage etc., true of idea partly Americas, North & South,—so permanent a breath cannot reside in space before island existed.—such an influence must exist in such spots. We know birds do arrive & seeds.' Then follows a parenthesis in different ink 'and geographical distrib division are arbitrary & not permanent. This might be made very strong. If we believe the Creator creates by any laws which I think is shown by the very facts of the Zoological character of these islands.' (I wish to thank Mr. P. J. Gautrey for confirming my deciphering of this difficult passage.) Occasionally, aware of the magnitude of his task, Charles writes a rhetoric question ('B', p. 224): 'The grand Question which every naturalist ought to have before him when dissecting a whale or classifying a mite, a fungus or an infusorian is What are the laws of life?'

The reading list at the end of 'C' begins with several accounts of voyages to which Charles refers in his Lyell annotations. The voyages are for the most part to regions visited by the *Beagle* and were read in the first instance to assist him in writing up his diary.

It was not until some time after March 1838 that a systematic reading of the whole of the *Magazine of Zoology, Botany & Continuation* was undertaken. This journal printed the papers by William Blyth, to which Prof. Eiseley has drawn our attention, Charles's comments on them can be seen in 'C', pp. 198–9. The 'Zoonomia' was read more than once after the *Beagle* voyage, certainly when 'B' was begun, and later on March 26, 1839, when some of Erasmus's references were followed up—notably Blumenbach's 'Essay on Generation'. The Spallanzani essay on the same subject was read April 24, 1840—this work is referred to in the 'Zoonomia' but it is not improbable that he also got the reference from a reading of the first edition of Baly's translation of Johannes Müller's *Physiology*. Sometime between May 18 and 27, 1839, we have the first mention of 'Lamarck II Vol Philo. Zoolog. references at the end of each chapter'. Only the first volume survives at Down in the 1830 Baillière re-issue of the sheets of the first (1809) edition—the water marks of the text are identical. This copy, still in its paper cover, has annotations in the text as well as at the ends of the chapters. He refers to this work on pp. 145, 148, 159 and 160 of 'E' as well as pp. 90 and 91 of 'N'. He speaks of Lamarck on 'E' 46, but here I think he is referring to the invertebrate treatise which he appears to have owned since his Edinburgh days. Prichard, *Physical Researches*, was read in the third edition on September 25, 1839, and *The Natural History of Man* sometime in 1841. Lawrence, *Lectures on Man*, was read April 23, 1847, in the 1822 edition, published and printed by Benbow. Charles's copy has a note on the back flyleaf, 'Zool. acceptation of Species etc. 225–232', but there is no annotation in the text. He writes against the title in the reading list, 'Poor'. Chambers's *Vestiges* was read shortly after November 20, 1844, long after the completion of his second draft in July 1844. The sixth edition of Lyell's *Principles* was read about March 30, 1841, and Charles plays a game on the back flyleaf scoring points in two opposed columns, one headed 'Lyell's' and the other 'Spec. Theory (Self)'. The pertinent comment is also made amongst many other notes, 'Lyell always considers that there is *saltus* between man & animals'. As we have already seen there is the first mention of *Malthus On Population* between

October 3 and 12, 1838. Charles read his brother Erasmus's copy of this work and there is, therefore, no annotation in either of its two volumes. Charles always seems to have borrowed a book whenever possible and only to have annotated books in his possession. 'D', as we have seen, has a later pencil note in Charles's hand: 'towards close I first thought of selection owing to struggle.' This fits in well with the reading of Malthus in early October. He read Malthus a second time, April 7, 1847.

During this same period, on the evidence of his pocket-book entries, Charles was writing up the Geology and Zoology of the *Beagle* voyage. He prepared the scheme in November 1837 but actually began work on the Geology. The writing of the Birds was begun in April, 1838 and continued in July the same year, together 'with some species theory'. It is shortly after that that we read in the notes to the Galápagos birds: 'When I see these Islands in sight of each other, & possessed of but a scanty stock of animals, tenented by these birds, but slightly differing in structure & filling the same place in Nature, I must suspect they are only varieties. The only fact of similar kind, of which I am aware, is the constant asserted difference between the wolf-like Fox of East & West Falkland Is^{lds}—If there is the slightest foundation for these remarks the zoology of Archipelagoes will be well worth examining; for such facts would undermine the stability of species.'

Thus the notebooks and the reading lists together show that the idea of transmutation had occurred to Charles before he became acquainted with his so-called influences. He had already received an immunising dose of transmutation, to adopt a currently fashionable analogy, and was accordingly well supplied with antibodies to similar ideas in other people's work when not accompanied by compensatory doses of solid information. It is partly on this account that Darwin has been accused of neglecting to show public recognition of his debt to his predecessors—but then so did Lamarck and most of the biological writers of the time. On this matter I give three passages from notebook 'D':

Page 69. Seeing what von Buch (Humboldt) G. St. Hilaire, & Lamarck have written I pretend no originality of idea (though I arrived at them quite independently & have used them since) the line of proof & reducing facts to law only merit if merit there be in the following work.

Page 71. In comparing my theory with any other it should be observed not what comparative difficulties (as long as not overwhelming) what comparative solutions & linking of facts.

Page 117. The line of argument often passed through my theory is to establish a point as a probability by induction & to apply it as hypothesis to other points & see whether it will solve them.

How far he had gone in developing his ideas the following passage on p. 4 of notebook 'E', October 4, 1838, will show:

It cannot be objected to my theory that the amount of change within historical times has been small—because change in form is solely adaptation of whole of one race to some change of circumstances; now we know how slowly & insensibly such changes are in progress—we feel interest in discovery & change of level of a few feet during the last two thousand years in Italy, but what change would such a change produce in climate, vegetation etc.

The origin of *The Origin* has clearly occurred; there remained twenty-one years of effort before its publication to the world.

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THE ART OF BOTANICAL ILLUSTRATION[1,2]

by

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WHAT I shall attempt in this paper is to give a brief general survey of the progress of botanical illustration, from the crude scratchings upon bone, made in paleolithic times, down to the highly sophisticated scientific drawings which illustrate serious contemporary botanical works. I have been urged to refrain as far as possible from technical terms and jargon which might be unintelligible to the layman; the temptation to use such terms is not great, since they would be equally unintelligible to myself. For I should confess, at the very start, what will doubtless soon become only too apparent—that I am not a trained botanist, but merely a painter with a passion for flowers. I know as little about chromosomes as I do about Biblical exegesis or Boyle's Law.

The first botanical drawings that have come down to us—drawings found in the paleolithic caves of France and northern Spain, need not detain us long. They consist of little more than doodles upon bone, and not even the most reckless botanist would risk his reputation upon attempting to identify the plants portrayed. For in all early civilisations the representation of animals precedes that of vegetables. And this predilection for a much more difficult and exacting task persists in the highly civilised arts of Egypt, Assyria, Crete, Greece and Rome. Plants do, of course, occur in ancient art, and on occasions they are treated with considerable naturalism; more often, however, they are stylised, and rarely if ever do they play more than a subsidiary part in a design which is primarily concerned with human beings or other animals.

There is a well-known painting of a lily (*Lilium candidum*) on a wall at Amnisos near Knossos. Made probably in the sixteenth century before Christ, it may perhaps be considered a botanical drawing in its own right; for though stylised, its identity is unmistakable. It is, however, as a decoration that it chiefly impresses; I am only surprised that no textile firm has as yet adapted it for chintz or cretonne.

It was the interest in plants for medicinal purposes that first caused them to be drawn with seriousness, and the earliest scientific drawings of plants were undoubtedly made to assist searchers after 'simples'. Pliny the Elder, writing in the first century after Christ, tells us that certain herbals of the previous century were illustrated, and that Krateuas, who was physician in ordinary to Mithridates VI Eupator, 'painted every hearbe in their colours, and under the pourtraicts they couched and subscribed their several natures and effects'. But, he adds, 'pictures are deceitfull' and cannot do full justice to the originals.

None of these illustrated herbals survives. But elements of their designs almost certainly persist in the earliest great manuscript herbal that has come down to us—the *Codex Vindobonensis* of Dioscorides, made, presumably in Byzantium, for Juliana Anicia, the daughter of the Emperor Olybrius. It contains amazing flower paintings, which date from the opening years of the sixth century A.D., and which set a standard of excellence that was not to be surpassed for nearly a millennium.

[1] Paper delivered to Section K (Botany) on September 8, 1959, at the York Meeting of the British Association.

[2] The majority of the illustrations mentioned, and a fuller treatment of the subject matter, may be found in Wilfrid Blunt's *The Art of Botanical Illustration*, published by Messrs. Collins.

There are about four hundred paintings in the book, executed upon vellum and in full colour and with such surprising naturalism that most of the plants shown are easily identifiable.

Ghiselin de Busbecq, ambassador from the Emperor Ferdinand I to the court of Suleiman the Magnificent, came upon the great folio in Constantinople in the sixteenth century and, as he tells us in one of his letters, attempted to buy it:

> One manuscript I left behind at Constantinople, one much worn with age, containing the whole text of Dioscorides written in capital letters, with painted representations of plants, among which are a few by Krateuas, unless I am mistaken, as well as a small treatise on birds. This is in the hands of a Jew, the son of Hamon, who while he lived was the doctor of Suleiman. I wanted to buy it, but the price discouraged me; for it was valued at a hundred ducats, a sum for the Emperor's purse, not mine. I shall not cease while I have influence with the Emperor to urge him to ransom this noble author from such humiliation. On account of its age the manuscript is in a bad state, the outside being so gnawed by worms that hardly anyone finding it in the street would trouble to pick it up.

But seven years later the manuscript was acquired, presumably by the Emperor himself, for the Imperial Library; and in Vienna, but for a brief exile in Venice after the end of the First World War, it has remained ever since.

Now admirable as the drawings in the *Codex Vindobonensis* are, it is almost certain that they were not made direct from nature. It was this process of copying and recopying, which persisted throughout the Dark and Middle Ages, that was to prove so disastrous to plant illustration. By degrees the copyists, misunderstanding the drawings that they were copying, or totally indifferent to their task, gradually reduced these naturalistic pictures to what were little more than patterns or arabesques—mere embellishments to the written page, artistically satisfying but scientifically valueless.

Of course there were exceptions. Occasionally an artist, confronted by a lacuna in the manuscript from which he was copying, was obliged to paint a plant—or the nearest equivalent to which he had access—from nature. Most of the figures in the twelfth century Herbal of Apuleius Barbarus, made at Bury St. Edmunds and now in the Bodleian Library, are completely stylised; yet a thistle, and one or two other plants in the same manuscript, bear every sign, for all their crudity, of having been painted from the living plant.

Towards the close of the Middle Ages a new attitude towards nature gradually became apparent. In the writings of St. Francis of Assisi and Dante there is an evident joy in the beauty of nature which has its visual counterpart in, for example, the chiselled foliage of the capitals of Rheims and Naumberg Cathedrals and Southwell Minster. These carvings are still primarily decorative; but they are not mere lifeless repetitions of current stylisations: they breathe a genuine love of leaf and bud and fruit.

At first, the truly realistic portrayal of a flower is a rarity. But with the dawn of the fifteenth century there breaks out, almost simultaneously in the art of France, the Low Countries, Italy and Germany, a naturalism such as has not been seen outside the Far East since the days of the *Codex Vindobonensis*. In Flanders the brothers van Eyck strew the green meadows of their great altarpiece with lilies and irises, and Hugo van der Goes is one of the many Flemish artists who place symbolic flowers in glass jars or *alborelli* at the feet of their Madonnas. Crivelli, in Italy, excels with his damask roses, and soon no altarpiece can be considered complete without its complement of flowers.

These painters must, in the course of their work, have made many studies of individual flowers; but such studies, once they had fulfilled their immediate purpose, were probably not considered worthy of preservation. At all events, not until the close of the fifteenth century, with the advent upon the scene of Dürer

and Leonardo da Vinci, do we find a sizable extant collection of botanical drawings by a major artist. Of Dürer and Leonardo I shall have more to say in a moment.

There are, however, several north Italian herbals, compiled in the second half of the fifteenth century, which are of considerable interest. Chief of these is the herbal of Benedetto Rinio, made in the Veneto about 1450 and illustrated with nearly 500 full-page coloured paintings of plants by an artist named Andrea Amadio who is otherwise unrecorded. These splendid drawings, which are now in the Marciana, caught the fancy of Ruskin, who wrote ecstatically of their beauty and engaged an Italian painter to make copies of them. Here, at long last, are botanical drawings which are in no respect inferior to those of the *Codex Vindobonensis*, painted more than 900 years earlier.

There is another field of art in which flowers were at this time treated with understanding and sympathy. In the borders of French and Flemish illuminated manuscripts we find floral borders which, though at first stylised, received towards the close of the fifteenth century a very naturalistic treatment. These borders show for the most part snippets of flowers painted in *gouache* in *trompe-l'œil* against flat grounds of gold or bright heraldic colours. This type of work culminated, in the opening years of the sixteenth century, in two superb manuscripts: the Grimani Breviary, a work of the Bruges-Ghent school, and the Book of Hours painted by Jean Bourdichon for the French Queen, Anne of Britanny.

The flower drawings of Dürer and Leonardo da Vinci, which I mentioned a moment ago, are well known and justly admired. Dürer's flower and animal drawings have, indeed, so captivated the designers of Christmas cards and the purveyors of petty prints for the small home, that there is some danger of his being remembered by the general public chiefly as a painter of buxom hares and pretty posies. Dürer's drawings are full of subtle observation, and are tenderly executed with Gothic crispness and angularity. Those of Leonardo, though made at almost exactly the same date, are more urbane and sophisticated, scientific in intention and Renaissance in feeling. All true lovers of flowers will prefer those of Dürer, who must certainly have had a real affection for humble plants; for Leonardo, flowers were merely one of the innumerable aspects of nature which aroused his insatiable curiosity. This lily (fig. 1), an early study and very different from the majority of his other flower drawings, was made by Leonardo in 1479 and has been pricked through for use in a painting no longer extant. Florentine artists of the *Quattrocento* must have made many such drawings, but few have survived.

The first printed herbal to be fully illustrated with woodcut figures of plants is the *Herbarium* of Apuleius Platonicus, published in Rome about 1481. Like almost all the *incunabula* herbals it perpetuated the stylised designs of an earlier age. The Narcissus from the *Ortus Sanitatis* of 1491, for example, is little preferable, as a piece of scientific observation, to the Manypeeplia Upsidownia of Edward Lear's *Nonsense Botany;* it requires some effort to remember that such work is contemporary with the drawings of Dürer and Leonardo. There are, however, one or two exceptions. In the *German Herbarius* of 1485, a few of the figures, crude though they are, were undoubtedly made direct from nature. But it is only too apparent that the best woodcutters of the day were not employed upon botanical works.

The first volume of the Herbal of Otto Brunfels, published by Schott of Strasbourg in 1530, marks the beginning of a new epoch in the botanical woodcut. The title of the work—*Herbarum Vivae Eicones*, 'Living portraits of Plants'—is significant, and the illustrator, Hans Weiditz, was a distinguished artist of the circle of Dürer. A whole world separates Weiditz's finely observed Dipsacus from the coarse figure of the same plant in the German Herbarius of a generation earlier.

The second great woodcut herbal of the period is the immense *De Historia Stirpium* of Leonhart Fuchs, published in Basel in 1542. This is a far more

FIG. 1.
Drawing of a Lily by Leonardo da Vinci
Reproduced by gracious permission of H.M. The Queen

ambitious affair. Its grand figures—there are more than double the number, and they are full-page—make at first sight a very favourable impression. Yet I would unhesitatingly award pride of place to the humbler cuts of the *Herbarum Vivae Eicones*. Weiditz accepted nature as he found her. If a leaf was torn, a flower drooping, he drew it thus—and with the greatest subtlety of observation. Fuchs's artist sought, or contrived, the perfect specimen—so perfect that it carries less conviction. Botanists may prefer the cuts in the *De Historia Stirpium;* artists will invariably choose the honest and more homely figures of the *Herbarum Vivae Eicones*.

I have taken these two books to represent the woodcut herbal of the sixteenth century. Though there are one or two others, of a rather later date, that are little if at all inferior to that of Fuchs, in general, in those published during the second half of the century, mere dexterity tends to replace the subtlety of observation found in the earlier works. This decline, gradual at first, accelerated rapidly after about 1590, when metal-engraving began to oust the woodcut. About the same time there was also a significant change in the type of plant illustrated: the herbal, or picture-book of *useful* plants, made way for the *florilegium*, which dealt primarily with garden flowers chosen for their beauty alone.

The cultivation of garden plants soon became a passionate pursuit throughout western Europe. The fenced medieval garden, with its emphasis on pot-herbs and vegetables, made way for the formal parterres of the Renaissance, prinked with exotic flowers—with tulips, crown imperials, irises, anemones, lilies and roses. And with this growing enthusiasm for flowers that were rare or beautiful came the demand from wealthy amateurs, and in France from royal patrons, for sumptuous picture-books illustrating the choicest treasures in the gardens of the rich. Thus it happened that many wonderful hand-painted florilegia were produced during the seventeenth century, particularly in France, Holland and Germany.

From the rich choice at our disposal I would mention two volumes made, about the middle of the century, by the Strasbourg artist Johann Walther for Johann, Count of Nassau. These books, which are now in the Victoria and Albert Museum, show the flowers cultivated in the Count's garden at Idstein, near Frankfurt-am-Main. The flowers are painted in *gouache*, with much vigour and a strong decorative sense. But, although they are sometimes stiff, and on occasions rise very artificially from the soil, they are botanically satisfactory. These charming volumes also contain sketches of the garden, grotto and summer-house; there is a particularly engaging frontispiece showing the owner and his family proudly surveying the little paradise that they have created.

Though the seventeenth century was the great age of the hand-painted florilegium, it persisted for a considerable time after. In 1720 Johann Simula painted a magnificent volume—a bulky folio with silver clasps—for the Count of Dernatt. It contains many varieties of the popular flowers of the day: 62 carnations, 54 tulips, 47 anemones, 39 irises, 35 hyacinths, and so on.

I have already said that in France the Court was the principal patron of the hand-painted florilegium. But before we turn to the work of the official court painters I would like to mention a very humble little book made by Le Moyne de Morgue, a Huguenot who escaped the Massacre of St. Bartholomew and was befriended in England by the Sidneys. It contains delicate, sensitive studies, probably made in France before Le Moyne's flight in 1572, which are now in the Victoria and Albert Museum. After studying the far more spectacular paintings of Ehret in the same collection, the student can still return with pleasure to these honest little paintings of unpretentious flowers.

It was Gaston d'Orleans, the younger brother of Louis XIII, who first gave royal encouragement to botanical painting in France. Having established a fine garden at Blois with the help of his wife's great wealth, he engaged the artist

Nicolas Robert to make a record of his best plants. These drawings, painted upon vellum, together with some made a few years earlier by Daniel Rabel, became the nucleus of a collection, known as the '*Vélins*'. Additions were made to it annually until 1905, and this great corpus of flower paintings, which fill more than a hundred volumes, is now lodged in the Muséum attached to the Jardin des Plantes in Paris.

Rabel was a versatile artist who also excelled in portraiture and designs for the ballet. A magnificent volume of his flower paintings is in the Bibliothèque Nationale, Paris. These are executed on vellum with the high finish of miniatures and, like most of the French court flower-paintings of the period, are bordered with gold.

Robert was the most prolific of the seventeenth century court painters. He is, perhaps, best remembered for the celebrated *Guirlande de Julie*, a florilegium of paintings of flowers accompanied by poems inscribed by the calligrapher Nicolas Jarry, which the baron de Sainte-Maure presented to his fiancée, Julie d'Angennes, before setting out in 1661 for the wars. This wonderful book, when it was exhibited in London in 1950, was fittingly described by a provincial newspaper as a 'floral tribute'.

The period from the close of the sixteenth century to the middle of the eighteenth century was the great age of the flowerpiece, with the Low Countries as the chief centre of production. This is a subject in itself, and important though it is it cannot be discussed here.

For those who could not afford the hand-painted florilegium or the flowerpiece in oils, the metal-engraved florilegium provided a cheap and admirable substitute. One of the most famous of these is the *Hortus Floridus*, or Garden of Flowers, of Crispijn vande Pas, published in Holland in 1614. Many of vande Pas's flowers are shown growing in the soil, set against the flat landscape and wide skies of the Low Countries. There are delightful touches of humour. Bees and butterflies fly among the blossoms, a mouse gnaws an upturned corm, a beetle explores the mysteries of a fallen leaf. The purchaser of the Hortus was expected to colour his own copy, and the author gives

> the perfect true manner of colouringe the same with their natural colours, being all in their season the most rarest and excellentest flowers that all the world affordeth, ministering both pleasure and delight to the spectator, and most especially to the well-affected practitioner.

The colours that he recommended—'lack, mayden's blush, sad yellow, masticott, verdigreece, and the like'—left much to the imagination, but there is an accurately coloured copy in the British Museum.

This is only one of many such books; but space is limited. From the close of the sixteenth century onwards, journeys to distant countries, made partly or wholly in search of new plants, gave the greatest stimulus to the botanical artist. One such traveller was the French botanist, Tournefort, who in 1700 was accompanied on his voyage to the Levant by Claude Aubriet, official flower painter to the French court. Aubriet sent back many admirable drawings. He worked for preference in *gouache*, in a style that is both forceful and accurate. The picture here shown (fig. 2), however, is one of a series of delicate little sketches in transparent monochrome, destined to illustrate a work by Antoine de Jussieu which was never published.

In North America, South Africa, India and Japan industrious botanical artists made records of exotic plants which stirred the imagination of the West. Many such plants were introduced at this time into Europe; others, however—the dahlia, for example, which was drawn in Mexico in the sixteenth century—were unaccountably neglected for many generations although they were admirably adapted to European gardens.

So far we have remained silent about English work. It is perhaps little realised,

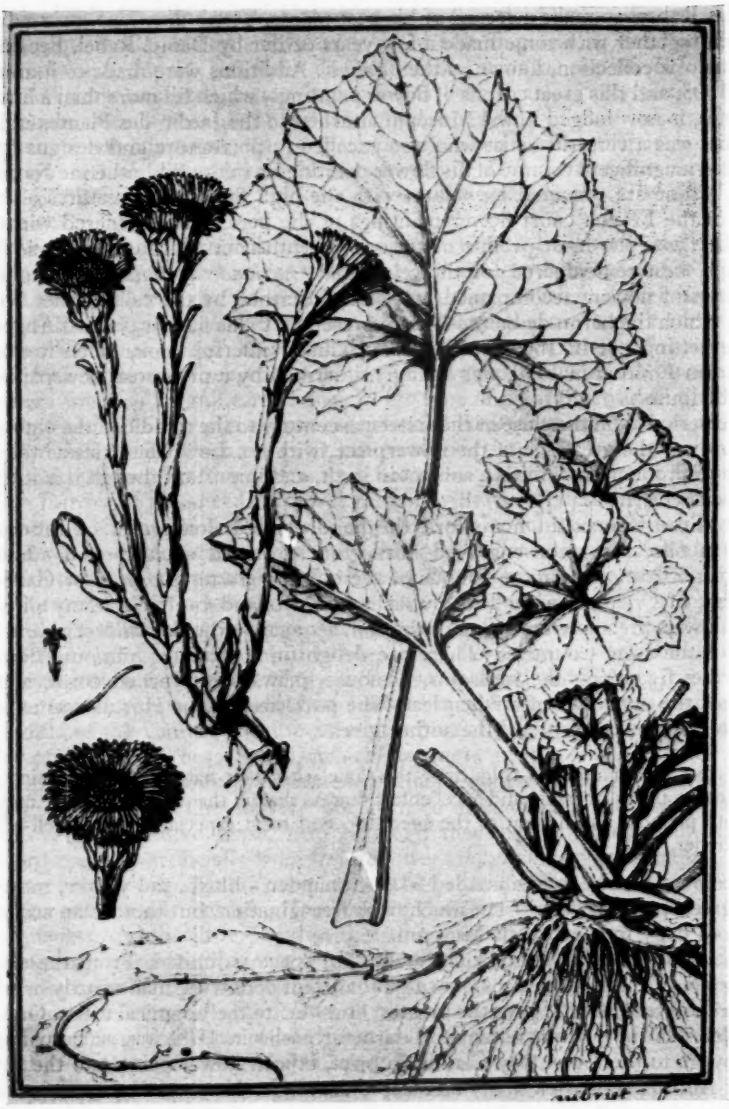

FIG. 2. COLTSFOOT (*Tussilago farfara*)
Drawing in ink and wash by Claude Aubriet (1665–1742)
By courtesy of the Lindley Library, Royal Horticultural Society, London

or little remembered, that popular English books such as Gerard's *Herball* (1597) and Parkinson's *Paradisus* (1629) were almost entirely illustrated by means of wood blocks borrowed from abroad or adapted from Continental prints. On the rare occasions when Gerard struck out on his own, he was not always very happy. His reputation was little enhanced, for example, by his cut of the 'goose-bearing barnacle-tree' from the Lancashire coast, and his statement that he was only

recording 'what our eyes have seen, and hands have touched' places him momentarily in the ranks of the Munchhausens. Yet he was quick enough to suspect fantasy in others, and rash enough to dismiss as 'mere fiction' a perfectly accurate figure of the Tigridia, a plant with which he was not familiar.

England certainly was late in the field of botanical illustration. But in the eighteenth century she began to play an important role, though, as with her earlier portrait-painters, her first considerable performers were foreigners who established themselves in this country. Jakob van Huysum, younger brother of the more illustrious Jan, worked for twenty years in England. But a far greater artist was Georg Dionysius Ehret, the Handel of flower-painting. The son of a Heidelberg market gardener, Ehret left Germany in 1736 and spent the rest of this life in England where he made spectacular paintings of the most notable garden plants of his day. He fraternised with the leading scientists, and taught flower painting, as he proudly notes, to 'the highest nobility in England. If I could have divided myself into twenty parts', he adds, 'I could still have had my hands full.'

There are some sixty superb paintings by Ehret in the Victoria and Albert Museum, and more at Kew and elsewhere. He used, for preference, *gouache* upon vellum, and like his French contemporary Aubriet, he succeeded in treating his plants decoratively without sacrificing botanical accuracy.

Two more foreigners—the Austrian brothers Franz and Ferdinand Bauer—reached England about 1790 and added lustre to British botanical art. Franz (or Francis), the elder, was unadventurous, remaining for fifty years at Kew making records of the plants introduced from all parts of the world in the opening years of the nineteenth century. Ferdinand, a born traveller, accompanied Sibthorp to the Levant and Flinders on his daring voyage to Australia, returning with sketches which he elaborated into finished paintings whose perfection remains unrivalled. Though their work is little known to the general public, they have good claim to be considered the greatest botanical artists of all time.

The most celebrated of all English flower books is almost certainly the *Temple of Flora*, a splendid folio published in parts between 1799 and 1807 by a young London doctor named Robert Thornton. The artists Thornton engaged—men famous in their own day though now little remembered except by their collaboration in the *Temple*—produced elaborately engraved plates, printed in colour and retouched with water-colour, of the Rose, the Lily, the Lotus of the Nile, the Pontic Rhododendron and other decorative plants. These were set in what Thornton termed 'appropriate' surroundings, though one may reasonably wonder how the Night-blowing Cereus would fare in the draughty setting of an English churchyard.

Thornton staked everything on this great book; and the gamble failed. As he wrote in an 'Apology' designed to explain its premature discontinuance: 'The once *moderately rich* very justly now complain that they are exhausted through *taxes* laid on them to pay armed men to diffuse *rapine*, *fire*, and *murder*, over *civilised* Europe.' In a last desperate fling he organised a gigantic Royal Botanical Lottery, under the patronage of the Prince Regent. 20,000 tickets were issued, at two guineas each, and the prizes, valued at £77,000, consisted of the original paintings, copies of the book, and unbound sets of plates printed with more speed than care. The lottery failed, and Thornton died penniless—but immortal.

The *Temple of Flora*, though it has immense period charm is a work of little scientific interest. Nor was its rival, Samuel Curtis's excessively rare *Beauties of Flora*, of much botanical value. Some of the plates in this slim elephant folio are the work of Clara Pope, wife first of Francis Wheatley of *The Cries of London* and subsequently of the actor Alexander Pope.

From these great show-volumes we turn now to humbler work of botanical importance. Between 1777 and 1787, William Curtis issued two fine folios, the

Flora Londinensis, illustrating the wild flowers growing within a radius of ten miles of the metropolis. His principal artists were William Kilburn, James Sowerby and Sydenham Edwards, the most distinguished of these being Sowerby. But Curtis, like Thornton twenty years later, was soon in financial difficulties. However, he guessed the cause of the trouble and saw the remedy: the public did not care for large plates of common flowers; it wanted small figures of the latest exotics to reach British gardens. In 1787, therefore, he began publication of *Curtis's Botanical Magazine*—the first and greatest of all botanical periodicals. Its success was immediate; as Curtis himself said, it brought him 'pudding' whereas the *Flora Londinensis* had merely brought him 'praise', and its publication has continued almost without interruption until the present day.

At the close of the eighteenth century, the only serious rival to Britain in the field of botanical illustration was France. Redouté, thanks to the royal patronage which made him famous during his lifetime and the glut of colour facsimiles of his paintings which have revived his reputation today, has become the most popular flower-painter of the present age. Yet some of his less remembered contemporaries —for example his master, Gerard van Spaendonck—were at least his equal in technical brilliance.

There is an oft-quoted thumb-nail portrait of Redouté by one of his contemporaries:

> A stocky figure with elephantine limbs; a head like a large, flat Dutch cheese; thick lips; a hollow voice; crooked fingers; a repellent appearance; and—beneath the surface—an extremely delicate sense of touch; exquisite taste; a deep feeling for art; great sensibility; nobility of character, and the application essential to the full development of genius: such was Redouté, painter of flowers, who counted all the prettiest women in Paris among his pupils.

The 'Raphael of Flowers', as he was called, was born in Luxembourg, and came to France shortly before the Revolution, where he was made welcome by the French court. But it was the Empress Josephine, a great patroness of horticulture, who made his name and financed the magnificent *Roses* and the other sumptuous flower-books so much sought after by collectors today. Redouté made big money and lived for a time in style; but he was improvident, and, like Thornton, died on the verge of bankruptcy.

That was in 1840. And though plenty of sound and valuable botanical illustration has been produced in France since then, the year marked the close of the French *de luxe* flower-book. But in England there still remained some demand for fine publications. Walter Fitch, for example, a typical Victorian, published no less than 10,000 lithographs, some of which were made for books designed to satisfy wealthy patrons of horticulture. A swift and faultless draughtsman with an almost mechanical dexterity, Fitch was closely associated with the Hookers and their great work at Kew. Someone who observed Fitch at work on his last important publication, the plates for Elwes's *Monograph of the Genus Lilium* (1877-80), said that he 'drew direct on the stone, without hesitation, and with a rapidity and dexterity that was simply marvellous'.

There was widespread interest in flowers in England and France during the nineteenth century; though this interest was in the main of a scientific nature, the sentimental was also much in evidence. Teach-yourself-to-paint flower-books were in great demand, and romantic little floral gift-books, full of pretty posies and indifferent verse, became the rage.

And what of the future? 'A great flower painter', wrote Goethe in 1831, 'is not now to be expected: we have attained too high a degree of scientific truth, and the botanist, who has no eye for picturesque lighting and grouping, counts the stamens after the painter.' It is true that, with the advent of photography, much of

the work that once could only be laboriously performed by the draughtsman was now swiftly and accurately carried out by the machine. But for scientific purposes, there are still certain things—enlarged dissections of plants, for instance—where the work of an artist remains preferable to that of the camera. That the *Botanical Magazine* continues to employ highly talented artists to make its illustrations, is evidence that even in a mechanical age there is, thank God, a place for honest craftsmanship.

Moreover, the demand, today, for flower-paintings seems greater than ever before. While volumes of old flower prints are being dismembered by the hundred for conversion into table mats, trays and waste-paper baskets, new talent is producing work which is technically the equal of that of Redouté. I mention one name only—that of Mr. Paul Jones, whose portraits of camellias are of the very highest quality.

This then, in brief, is the pattern of the development of botanical illustration. And in what remains of the space allotted to me I would like to say a word about the problems that confront the botanical draughtsman. The portrait painter and the landscape artist, infuriated by unpunctual or restless models, by changing lights and shifting skies, may feel that the botanical draughtsman has a relatively easy job. But only those who have attempted to draw flowers can appreciate that they refuse to pose like fruit and the customary paraphernalia of still life. Petals open and close, stems curve or straighten themselves in a matter of minutes. Cézanne, in despair, was reduced to using paper flowers for his still-life compositions. Further, the colours of many flowers are so vivid that at the best they can only be approximated in paint. Moreover—and this is by no means easy—the botanical artist must serve two masters—Science and Art. The greatest flower painters have been those who have understood plants scientifically yet seen and described them with the eye and the hand of the artist.

There is no better way of getting to know a plant than by drawing it. Many flower-lovers, though quite untrained as artists, have derived infinite pleasure and much knowledge from drawing, however falteringly, the plants in their gardens. The better we come to know our plants, the more we shall enjoy them.

PHYSICAL EDUCATION

SECTION I (Physiology and Biochemistry) and Section L (Education) devoted the morning of Wednesday, September 9, 1959, to a discussion on the problems of physical education. The symposium was introduced by Mr. R. St. G. T. Harper, Director of the Department of Physical Education at Manchester University. Mr. A. D. Munrow, Director of Physical Education at the University of Birmingham, then presented a paper reviewing the application of mechanics to physical skills and activities. He was followed by Miss Ruth Foster, Staff Inspector of Physical Education, Ministry of Education, whose contribution dealt with the analysis of movement. The symposium concluded with a contribution from Dr. W. F. Floyd, Senior Lecturer in Physiology at the Middlesex Hospital Medical School, on the patterns of muscle activity in movement and posture.

INTRODUCTION

By R. St. G. T. Harper

(*Director, Department of Physical Education, University of Manchester*)

It is interesting to note that as early as its Meeting at Glasgow in 1855 the British Association discussed 'The application of physiological principles to gymnastic education'. Since this time there have been many references at subsequent Meetings. Again it is of especial interest that at the Meeting in York in 1906 Professor Sadler referred to the 'wholly new stress laid on the physical side of education'. In 1935 came the first allocation of a full discussion on physical education, and in 1953 at Liverpool one on the physiology of athletic training.

The great increase over recent years in the facilities for international conferences and personal visits has led to a better understanding through first-hand experience of concepts in other countries, but this will not be a world-wide review. Reference is to work and developments as they refer to Great Britain. Foreign influence, as of Ling, Bergman Osterberg, Niels Bukh and Laban, has always been strong, if not predominant, but in the last decade, perhaps more than ever before, originality has been displayed at home and successful efforts have been made to adapt physical education to the British way of life.

Members of every generation will have some appreciation of the development of physical education—from the Education Act of 1875, in which it was laid down that 'A child may attend for not more than forty hours in the year at a nearby barracks for instruction in drill', to the McNair Report on which the Act of 1944 was based and which contains the following:

> The training of a man or woman to control groups of children in movement and out of doors is of fundamental importance in modern education and its techniques have a value in teaching generally—and are by no means applicable only to physical education.

Here, then, is the mainspring of developments of the last ten years; the synthesis of physical with mental education, a synthesis demanded by Professor M. L. Jacks of Oxford at a Meeting of this Association, a quarter of a century ago. Nevertheless, there is still prejudice to be overcome in this respect. It is depressing to read that F. T. H. Fletcher, in submitting a paper on the educational needs in the ten years 1966–75 to the Central Advisory Council for Education (England), says: 'The English child, *because of the greater emphasis on physical education in our schools*, is considerably less intellectually advanced at the end of his school

career than is his French counterpart.' What right has Mr. Fletcher to make this categorical statement, and is it likely to affect the evolution of curricula to be introduced for this decade?

One of the important contributions to this synthesis has been the raising of the level of intellectual capacity of the men coming into physical education. Right up till the 1930's physical education for boys was largely in the hands of ex-Service instructors. For girls, it was different, and we should have been unwise to leave a woman out of our list of contributors to this symposium. Today the majority of universities throughout the United Kingdom have one or more lecturers in physical education, and three have independent academic departments. At one, physical education can be taken as a subject for study for a first degree, and at others, is taken as the basis for postgraduate studies.

It is perhaps significant of the alteration in the status and place of physical education that it is commonly felt today that the name is misleading, still indicating, as it does, a separation of this aspect of education. I was, in fact, invited to think of an alternative title for this symposium. Much as we should like to comply, we have so far failed to find the answer. 'Kinetics' covers only the science of movement, and physical education is largely concerned with the art, but 'the Art and Science of Movement' still leaves out some of the most fundamental educational elements in physical education, which, in fact, are not directly concerned with movement at all.

This leads me on from my first point—'synthesis', to my second point—'scope'. This again has developed out of all knowledge in the years since the end of the war. It is a sad fact that war, or the threat of war, seems to be a necessary stimulant to developments in education, and in particular in physical education. History has proved this time and time again. In the last war civilian experts, both men and women, were drawn into the physical training of the Services and their old methods were revolutionised. Here again synthesis was developed and the physical training was adapted to other aspects of military training. When the civilians returned to peacetime teaching and organising they took this realism with them. Physical education broke out of the gymnasium and the playing-field, and spread to the mountains and rivers. Even in the precincts of the school, exciting and challenging pieces of apparatus were set up. Today the number of activities and the variety of the skills involved in performing them is fantastic and far beyond the capacity of any single person. Consequently, if a broad syllabus of physical education is to be offered in school today, it cannot be carried out by the 'specialist' alone: every member of the staff must have his or her own particular interest and share. This, of course, in its turn contributes to the synthesis of the education of the child.

Our main purpose in the papers which follow is to show that within the last twenty years physical education has become far less of a hit-and-miss affair. Every year it becomes based more and more on a scientific study of the needs of the child or adolescent.

Today, physical education is integrated into the syllabus, and the physical education specialist into the staff. The training of every teacher today involves not only recognition of the needs of the child in every aspect but, wherever possible, practical as well as theoretical study and, above all, training in observation of the child in every facet of its daily life. If the teacher is constitutionally averse to, or incapable of, taking any part in the physical programme, at least he or she can be, and today usually is, capable of discussing intelligently with the physical education specialist, problems which very often can only be solved by them mutually and not alone.

May I say something briefly about the other contributors to the symposium? Mr. Munrow has spent the last twenty years on the staff of Birmingham University

and has taken the fullest advantage of the opportunities presented to him for research and collaboration with other departments. Miss Foster has spent the last fifteen years at the head of this aspect of education at the Ministry. She, more than anyone else, has therefore had to carry the responsibility of studying, sifting and moulding the very controversial new ideas. Dr. Floyd, whose work on problems of muscle activity is so well known, represents ideally the bridge which has been built and is continually being strengthened between physical education and those in the medical profession concerned with positive health.

THE APPLICATION OF MECHANICS TO PHYSICAL SKILLS AND ACTIVITIES

By A. D. Munrow

(*Director of Physical Education, University of Birmingham*)

When we study an individual performing a physical activity, one particular aspect of his performance may be uppermost in our minds. We may be concerned primarily with the relative effectiveness of his movements in relation to another person; thus, when we watch competing tennis players or fencers, we are concerned to see how one technically outmanoeuvres the other. On the other hand, when we go to the ballet, we are concerned primarily with the aesthetic impact of the movements we see. Yet another viewpoint is that of the experimental psychologist, looking beyond the movements themselves to the effects on performance of stress or fatigue or the changes in performance resulting from changes in the information to which the performer responds. The physiologists may be concerned primarily with the changes in respiration and circulation which the physical performance demands and with the individual's capacity to sustain the required movements for a required time. The physicist may simply view the human body as subject to the laws of Newtonian mechanics.

The physical educationist may be concerned with all these, and all represent valid fields of study within the total study of physical education. This may seem, perhaps, tediously obvious, but I believe it needs saying. There is a tendency on the part of those whose primary concern is aesthetic movement to consider that mechanical considerations are in some sense antagonistic to aesthetics. This should not be so. Similarly, to understand fully the mechanics of a movement is not to have said the last word about performing it, any more than a full knowledge of an internal-combustion engine is the sole requisite for good driving.

But a knowledge of underlying mechanical principles does occasionally help the performer and should always help the teacher or coach and enable him to sift the grain from the chaff of the changing fashions in technique.

In my own department in the University we have attempted to study the mechanics of physical skills. The skills have been grouped according to certain mechanical factors which they possess in common.

I. There are those skills in which one is concerned with applying forces to another object to project it through the air. We refer to these as *Throwing Skills*. These involve problems of the successive application of forces from various parts of the body and their timing (so that each muscle group applies its force at the moment of minimum acceleration and maximum velocity achieved by the previous group) and of keeping contact with the missile for as long as possible while subject to the restrictive space conditions laid down by the laws of the event concerned.

II. When the missile is itself physically separate from us and we have to influence its flight during extremely small periods of time, we come into the area of

Striking Skills and deal mainly with problems of instantaneous exchanges of momentum between the missile and the striking implement.

III. In both these skill groups, what we do is conditioned by what we know to be the likely subsequent behaviour of the missile itself, and so we need to study the *Aerodynamics of Various Types of Ball and other Projectile*.

IV. Substantially different mechanical problems arise when one is concerned with the application of force in order to lift or carry or pull or push an object as in tug-of-war, Rugby scrummaging or weight-lifting. These we usually call *Heavy-object Skills*, and there are considerable applications to industry as well as to sport in this area of study.

V. We may be concerned, in so-called *Friction Skills*, with exploiting different qualities and quantities of friction available in movements such as skating and skiing.

VI. We are also concerned with the body exerting forces in order to move itself in various ways. (a) The problems in this field are unique when the body applies forces to water and moves in the same medium. *Swimming*, therefore, constitutes a sub-group on its own. In (b) *Swinging Skills*—mainly gymnastics, but including pole-vaulting—one is concerned with overcoming or exploiting problems of radial forces, and finally, in (c) *Gravity Skills*, one is concerned with the body applying forces to the ground and eventually leaving the ground at point *A* and landing on it again at point *B*. Athletic long- and high-jumping, many gymnastic skills and diving are some of the skills falling into this group.

I have briefly outlined six groups, in which there are mechanical problems to be studied if we wish to understand physical skills more fully. I propose now to focus down on the last sub-group of *Gravity Skills* and give a few details of the methods of study we have used to gain more information about it.

We have used slow-motion filming to obtain a record of the skill. This has subsequently been analysed by a method of tracing the film, frame by frame, on to paper. The method is simple but time-consuming. Each frame is projected horizontally and reflected through a mirror held at 45 degrees up to a glass-topped table. Paper is placed on the table and the relevant tracings made from the image.

Because the body is continuously changing its posture during the performance of the skill, we need to know the path of its centre of gravity rather than the path of any particular limbs or body segment. For this purpose the traced outline postures are transferred to a large board six feet by four feet and at the same time expanded back to life size. The original performer now lies on the board and is fitted into the outline posture, the board resting at its corners on four weighing machines. By a very simple calculation the position of the body's centre of gravity can now be determined and pinpointed back in the original tracing. We need two further references for each frame of film—a distance reference and a time reference. The distance reference is marked in on the background wall before the original filming, due allowance being made for the difference between the background wall and the plane of the actual movement performed, in relation to the position of the camera. For a time reference we have taken the interval between frames to be constant and to be one-seventieth of a second. Fairly frequent checks of our camera speed have shown these figures to be reliable, certainly within the limits of the other data with which we are working.

Clearly we can now plot displacement curves from our film tracings. From these curves it is easy to calculate average velocities for, say, each seven frames of film (we chose seven frames because this conveniently gave us $\frac{1}{10}$ sec. as the time interval in each case and facilitates calculation), and hence we arrive at velocity curves. By a repeated similar procedure, acceleration curves are plotted and we are then in a position to calculate forces.

The whole procedure is time-consuming, but (*a*) it has gradually evolved: in the

early investigations we were not sure just what we were looking for or what was the limit of accuracy of our methods; (*b*) it is a relatively cheap form of investigation and we have no access to large research funds; (*c*) it is surprisingly accurate. Working backwards from films of moving shots, the gravitational constant by this method has varied between 31 and 33 ft/sec^2. In the most recent analysis of a physical skill, with all the additional errors of centre of gravity determination, the vertical acceleration of the human body once it left the spring-board was calculated as 30 ft/sec^2.

Perhaps it will now be of most interest to discuss in general terms some of the mechanical considerations involved in gravity skills.

In many of these skills the body needs to rotate in the air between the time of take-off and landing. A high-jumper, for example, leaves the ground approximately vertical and by the time he reaches the lath needs to be approximately horizontal. A long-jumper leaves the ground with a slightly forward lean from the vertical and needs to land with a slightly backward lean. A diver may need to turn over as many as two and a half times about a horizontal axis before reaching the water. One problem here is to know just how an individual may obtain angular momentum during the period of take-off.

Essentially there is only one way. The forces acting on the individual can only be applied through his area of contact with the ground, namely his feet. If the line of action of the resultant of these forces passes through the individual's centre of gravity, no rotation will take place. If it passes outside, rotation will be set up. But, in practice, the force evoked from the ground differs in magnitude and direction at differing periods of the take-off. Take-off itself varies in duration. Using a standard gymnastic springboard in one particular vault, the total time of take-off was estimated as 0·14 sec. The corresponding times using a trampette and a trampoline were 0·24 sec. and 0·46 sec. respectively.

We have therefore found it convenient to separate certain components of the forces acting at the feet and to consider them separately. They are as follows.

1. *Initial checking movement at the feet.* Just prior to final contact with the take-off surface, the foot is moving. It is then checked at the moment of impact. Clearly a force is applied to the feet at this moment. If the action of this force passes outside the centre of gravity an initial rotation will be set up. Obviously this factor is greater (*a*) when the take-off surface is rigid or nearly rigid and (*b*) when the body at the moment of impact is held rigidly. Modification of either of these factors can minimise this effect.

2. *Gravity couple.* During all the time that the body is in contact with the ground, the body's weight is acting vertically downwards through the centre of gravity. In a backward-leaning position this will cause backward rotation (or decrease forward rotation), and in a forward-leaning position conversely.

3. *Recoil force.* In so far as the take-off surface is non-rigid but elastic the body's kinetic energy at impact may be transferred to the take-off surface, and re-transferred to the body in the elastic recoil of the take-off apparatus at a subsequent time in the total take-off period. The line of action of the recoil force is normal to the surface.

4. Before the individual has finally lost contact with the take-off surface, he can, by appropriate limb or trunk movements, get various parts of the body already moving in the direction in which he wants to go. This rotation of various parts of the body can later be redistributed to the whole body as limbs come to the end of their range of travel or as the body makes itself rigid by muscular contraction. We usually refer to this type of action as *storing of angular momentum.*

5. In most, or at any rate many, gravity skills there is a final energetic straightening of the take-off leg or legs which thus applies a considerable force to the take-off surface and hence evokes an equal and opposite force from that surface. If the body

posture is such that its centre of gravity is outside the line of action of this leg-thrust, further rotation will be set up. This we call *off-centre thrust*. This is not a good term, since all these forces are, in effect, off-centre thrusts.

6. In a final ankle extension, the ground can be, so to speak, clawed backwards under one if the frictional properties of the take-off allow this to happen, and so we speak of exploiting the *frictional thrust*. This again is a loose phrase, since any force not normal to the surface involves a frictional component.

Let me repeat, then, that over the whole period of final contact with the ground or take-off surface, there is a continuous resultant reaction at the point or area of contact. It varies in magnitude and direction, and varies also in its relation to the body's changing position. Throughout this period, too, the body's weight is acting through its centre of gravity. We have found it convenient to split what is essentially a continuous variable into six separate factors, but in fact they need be thought of as blending in any given physical skill. Nevertheless, some principles of coaching can be applied by stressing one or other of these factors.

In very general terms a number of principles can be stated as follows:

1. To achieve maximum height or distance, a given force should be applied so that its line of action passes through the body's centre of gravity. To achieve some angular acceleration from the same force, one will have to trade some linear acceleration.
2. By forward flexion at the hips it is comparatively easy to bring the body's centre of gravity away from the line of action of the leg thrust. Hence forward rotation is most easily achieved by this means.
3. By contrast it is difficult to bring the body's centre of gravity behind the line of action of the leg-thrust, and backward rotation has to be achieved by a greater emphasis on 'storing' through the preparatory swing of arms or of the trunk itself or of the free leg in a single-footed take-off skill.
4. Provided muscular strength is adequate to achieve adequate acceleration, greater storage will occur by swinging a limb in an extended position in which its rotational inertia is greatest.
5. Once the body has left the ground and becomes a free system, its total angular momentum cannot be changed, but changes in body posture may modify the moment of inertia and hence the body's rotational velocity.
6. Just as rotation can be 'stored' prior to take-off, total body rotation can be redistributed during flight. This enables inconvenient rotation of a particular part of the body to be delayed.

I must stress that our work to obtain more accurate data and information is still in a very elementary stage. We need apparatus to determine the body's moment of inertia or rotational inertia in different postures and about different axes. A force platform would enable us in certain skills to obtain much more detailed data more readily about forces being applied. I hope both these developments will go ahead in the coming session at Birmingham. Some of this work is new, but I must stress that some is far from new. Professor Sir James Gray, this year's British Association President, has worked in this field, studying the locomotion of animals for many years.

Professor Cannon once referred to 'the wisdom of the body'. It is a significant phrase. Most of the exceptionally 'wise' people who achieve new feats of skill or improve old techniques, do so through their innate neuro-muscular wisdom. It is not likely that theoretical considerations will enable us to predict new and better techniques, but they should enable us to understand the basis of those in existence.

It is surely intellectually satisfying, and even exciting, to understand these things. May I remind you of the opening remarks of this lecture. Any aspect of physical activity represents a valid field of study. But physical activity itself,

physical education or, as I should prefer to call it, sport, using that word in its widest possible sense, is an aspect of human activity or culture in its own right and one which I believe should play an increasingly important role in the life of industrial urban societies.

THE ANALYSIS OF MOVEMENT—A CURRENT CONCEPTION AND THE REASONS FOR IT

By Miss Ruth Foster

(*Staff Inspector for Physical Education, Ministry of Education*)

In this paper I attempt to discuss certain aspects of the movement of human beings. For my purpose there is no better definition of movement than that of the *Oxford English Dictionary*—'the process of moving'.

There are, and have been in the past, many attempts to analyse movement, usually for a particular purpose, and to meet a specific need. So one finds treatises, or books of instructions, in which the actions proper to the development of skill in such activities as athletics, swimming, fencing, piano playing, ballroom dancing and even cookery are analysed and described. The aim of such analyses is, perfectly properly, limited to a particular field, and usually to particular patterns of movement within that field. So one finds chapters on the back crawl, the backhand, the pole vault and the spin turn, and one knows how baffling such analyses can be because, in distinguishing the separate elements, synthesis, which makes sense of the action, is lost. The more knowledgeable one is about the activity in question, the more illuminating such books can be because kinaesthetic experience supplies the necessary synthesis.

Over and above these analyses of particular actions attempts have been made, from time to time, to analyse movement in a more generalised way, and with a less particular purpose. To this category belong the various systems of gymnastics, the Motion and Time concept used in industry, and I include also the work of Dalcroze, a professor of harmony who described the physiological faculties of the musician as 'delicacy of aural perception, nervous sensibility, rhythmic feeling, i.e. the true sense of the relations between movements in time [by which he meant music] and those in space'. From this point of departure Dalcroze proceeded to develop his general scheme of relationships between music and movement which he called Eurhythmics.

The various systems of gymnastics have usually had, as a general aim, the attempt to compensate for the loss of activity and of vitality brought about by life in an industrial society and, especially, by the restrictions of the classroom. The implicit assumption has been that gymnastics could provide, in concentrated form, in short periods of time, and in confined areas of space, the kind of education in movement that would make for health, and that would also lay the foundation for skill in activities such as athletics and games.

The Finnish teacher Elli Bjorksten, whose work had a considerable influence in this country, and whose books were published in English in 1932, was undoubtedly a woman of vision. She was aware that at least one authority held that movement played an important part in perception; she agreed, with others, that the state of the body affected the mind; but she was ahead of many, at least in the field of physical education, in appreciating the effect of the state of mind on the body.

But far as her vision reached, Bjorksten and others like her who sought to provide a generalised training in movement had not the means necessary to attain

their aims because of the limitations imposed by the analysis of movement then available. As is well known, the analysis was, fundamentally, an anatomical one; that is to say, movement was analysed in terms of the parts of the body, each of which were exercised in turn, usually in isolation. It is true that various qualifying terms were used, and that the conception of 'rhythmical swing' influenced the mode or quality of action, but, fundamentally, the analysis rested on structure and the language used was concerned with parts.

It would, of course, be ridiculous to disregard structure, but as an analysis on which to base a general education in movement it is inadequate because it is concerned with the displacement of the limbs from one point to another, and not with movement considered as process. In practice this mode of thought led to an emphasis on isolated movement, and restricted observation to a point where Bjorksten was able to write of the action of a mettlesome horse in these terms: 'it has rhythm, beauty and grace in every movement; it seems almost to dance; each step is so light and elastic that the hoofs touch the ground for only a fraction of a second; *the leg is raised in complete isolation*'(1). We do indeed see what we look for.

I have referred (*a*) to the analyses of movement belonging to particular patterns of action in certain acts of skill such as strokes in games; (*b*) to the more generalised analyses of industry, of Dalcroze, and of gymnastics (which, of course, have particular aspects), and I turn now to that current analysis to which the title of this lecture refers. This is the analysis of Rudolf Laban, who described movement in terms of Space – Time – Energy.

When Laban came to England as a refugee in 1936 his name was associated in the first place with the art of dance, but although he was perhaps more continuously involved with dancers and workers I think that it is true to say that he was primarily interested in people, and that he developed his analysis in order to be able to discern their needs and develop their powers.

Laban's industry was immense, and much of what he wrote remains unpublished, so that my account of this particular contribution is likely to be incomplete and inadequate.

In the first place, the analysis permits a generalised mode of thought which is extremely fruitful; it opens up infinite possibility in the field of movement, and within these ultimate conceptions of Space, Time, Energy, both the more particular descriptions, such as those of actions in games, and the more mixed, such as rhythm and momentum, have perspective.

In the second place, unlike the anatomical analysis, this one is concerned with process (and you will remember that the *O.E.D.* defines movement as the process of moving), that is to say, in the 'going on' of movement. The terms used, namely Space – Time – Energy, to analyse process reveal the quality of the process, and, since movement is essentially transitory, this is rather like being able, at last, to put salt on the tail of an elusive rabbit.

In the third place, Laban's mode of thought permits both analysis and synthesis. Every movement traverses space, and this takes time, the one implies the other, and every movement involves a degree of energy; but the three elements are inseparable, one cannot be altered without modifying the others and therefore the whole. Slow-motion photography provides a vivid illustration. In slow motion the qualities of space and energy remain the same, but their relationship to time, as presented on the screen, is altered so that an interesting, and sometimes amusing, transformation takes place.

These then are the three features of Laban's analysis that I wish to emphasise: (1) the high level of generalisation; (2) the description of process which it makes possible; (3) the opportunity for both analysis and synthesis. I now want to consider rhythm in the light of these conceptions.

The teacher of gymnastics has usually emphasised the metrical or pulse-like aspect of rhythm. Bjorksten, who, after all, was noted for her emphasis on the 'rhythmical swing', wrote: 'Sense of rhythm is "the ability to recognise divisions of time in regular measures, and to regulate one's own movement to those measures".' Her examples, the first of which was that of marching, leave no doubt as to her meaning. She limited herself to one conception of rhythm, and it is not one that helps, for example, the tennis player or the diver, whose actions fall into phrases comprising a flux of efforts which are rhythmical, and successful, when the right amount of energy is applied in the right direction at the right time. In action we may compensate for lateness in time, or deviation in space, by the application of extra energy; we achieve a successful outcome by 'brute force' but the action is rhythmically distorted. It is noticeable that a skilled player, dancer, or craftsman always appears to have plenty of time, to command the space around him and to be effortless.

A contemporary writer says: 'The essence of rhythm is the preparation of a new event by the ending of a previous one. The movements of a person who moves rhythmically are complete gestures in which one can sense a beginning, intent and consummation, and in which one can perceive in the last stage of one the condition and rise of another.—Everything that prepares a future creates rhythm.'(2) How often one sees an inept player lift a racquet or a bat, a diver stand on the board, a fielder move to a ball, and says to oneself, 'There is no future in it'. We may explain it by saying, 'He wasn't ready', but this is not sufficiently discriminating; the rot may have set in anywhere—in lateness in time, in snatching at time, in an inadequate combination of speed and strength, or in direction in space. I find that Laban's analysis illuminates Langer's description of rhythm, and I suggest that an understanding of what constitutes rhythm is important to all of us who are concerned with the study of movement.

Now I must turn to the reasons why, to many people, Laban's analysis seemed to be timely.

In this half-century one of the outstanding characteristics of our society, and therefore of our schools, has been an increasing concern for the individual. As this idea has grown, society, including the school, has created a situation in which the individual has been revealed, rather than concealed, with the result that knowledge, understanding, and discrimination of the needs of individuals, together with the means of meeting them, have been developed.

Another, and complementary mode of thought conceives the individual and his experiences as a single and whole event, rather than distinguishing between the individual and the experiences doled out to him. For example, language is not merely taught to and received by the pupil, but language is, rather, a medium used, modified and in turn modifying, a child's mode of living.

The changed relationship between parents and children, teacher and pupil is a natural concomitant of these ideas and practices, and with this change in relationships the mode of communication between adults and children has also changed.

Within these contexts, which go far beyond a mere change of method, it was inevitable that physical education should change. In 1933 Lindhard wrote: 'One must not close one's eyes to the fact that one of the most frequent causes of correction during a gymnastic lesson is that the pupil is not in line with the others.'(3)

Lindhard was a Scandinavian, but what he wrote was true of much of the work in this country. Indeed, I seem to remember that even in 1945, when men returned to teaching after the war, they were considerably shaken because, in a number of schools, straight lines, work in unison and commanding had vanished. The landmarks had disappeared and, understandably, they did not know how to look at what they saw, much as a teacher who had never taught young children finds herself completely at a loss when, for the first time, she finds herself confronted

with the varied and individual activity that goes on in most infant classrooms. Her terms of reference are inadequate and she does not know how to look at what she sees. I have the same kind of difficulty in looking at American football. I know nothing about it, so that what I see means very little.

If, as is usual nowadays, children are given opportunities to experiment, for example, on apparatus, I suggest that it is very difficult for a teacher to understand what is happening unless some such general analysis as Laban's is available to guide his observation. Unfortunately, changes of method are not always based on the changes in thought from which they arise, so that full use is not made of fresh opportunities.

There are other aspects of movement not solely connected with physical education which also seem to demand a generalised form of analysis. In the first place movement is slowly coming to be regarded as having significance outside those periods in a school programme that are devoted to it. Increasingly teachers seek to understand their children's development in terms of movement; they are not content merely to discern what is done, but also wish to be able to recognise characteristic quality. After all, a growing child's idea of himself is of considerable importance to his development; it is built up in various ways, and not least through action, both functional and expressive, where the body is, as it were, both the instrument and medium of the self. It is by virtue of the body that we exist, it is our medium of contact with the world, and it is the means whereby we begin to perceive distances, heights, depths and planes.

Russell Brain writes in his third lecture on 'The Nature of Experience':

> . . . the visual appearance of an object, such as a book or an apple, implicitly conveys to us its feel and its weight. Moreover, its position in space sketches out, as it were, the potential movements which we should have to make in order to reach and grasp it, and movement involves time. Hence, what seems a simple visual percept is never purely visual, but includes memory-traces of other sense-data and is set within the space-time of a percentual world common to all senses.

He also quotes the following passage from Collingwood:

> . . . 'the spectator's experience on looking at a picture is not a specifically visual experience at all. What he experiences does not consist of what he sees . . . it does not belong to sight alone, it belongs also to touch.' He goes on to amplify this as meaning not only tactile values, but distance, space and mass-motor sensations and images.

So movement plays its part in the development of perception, and this is one reason why movement is an insistent need of young children.

Movement is an important factor in all sorts of situations: in sheer necessary locomotion, in craftmanship, and in athletic activities of many kinds. It is also a means of expression—together with the voice the most immediately personal. Motion and emotion are very closely linked, and just as feeling gives rise to action, so, in turn, action may modify feeling. There are many words that connote motion and emotion, or mood and attitude: *excited*, *agitated*, *depressed*, *elated*, *deliberate*, *calm*—to mention only a few.

Emotion may overflow, for example, in tears, or may be discharged in exclamation, or in a blow, but to express is to give shape and form to ideas and feelings and so to come to terms with them. This process, whether the medium is pigment, clay, words or movement, is an important one in achieving maturity.

If, as I have suggested, the trend of thought in society and in schools has tended, increasingly, to reveal the individual and his needs; if it is true that there is a new conception of the relationship between the individual and his experiences, and between adults and children, and if movement is regarded as being of increasing significance in the development of children, then these seem to me to constitute the reasons why Laban's analysis is timely.

Our forerunners reached towards a horizon but had not the means to understand what they dimly perceived. It is our good fortune that we have a means which has extended our thinking and, in consequence, our seeing. In *Man on His Nature*, the great physiologist Sherrington wrote in the course of a dialogue between Nature and Man, 'Try then to teach your sight to grow.'(5) This is one of the most important possibilities which Laban's analysis presents to us.

There are circumstances in which it is enough to know all there is to know about, for example, tennis, swimming, or Scandinavian dancing, and there are circumstances when a consideration of structure is of the first importance. Laban's analysis does not supplant such knowledge, it rather throws new light on what is known and extends our reach.

Since I have suggested that Laban's analysis provides us with a high level of generalisation, it will be clear that the term 'basic' which is sometimes used in this connection appears to me to be inappropriate, although I would agree that this analysis may well form, and indeed does form, the basis of many teachers' thought and practice. The transfer of training is a question which concerns some. I suggest that children who are accustomed to explore, with concentration, the attributes of space and the gradations of speed and strength develop very vivid kinaesthetic images of these qualities, and, in so far as this happens, it is these images, rather than patterns of movement, that can be called upon in other contexts. If, for example, an action in a game calls for an element of extreme directness, extreme suddenness, or perfect steadiness, then, in so far as these qualities are known as vivid kinaesthetic images, they can be brought into play. Similarly, if a coach finds that certain necessary qualities are lacking, he can design a general training period in which the qualities can be emphasised, developed and understood. The emphasis would, of course, differ according to the kind of activity in question.

Some have objected to Laban's analysis on the grounds that it was developed only in connection with expressive work (which is not true), and that it is, therefore, not valid in connection with any other kind of action. This is rather like suggesting that we need two languages, one to be used for utilitarian purposes—to buy a ticket or to order the groceries—and another for poetic purposes—to write a love letter or a poem. If Laban's analysis is valid, I suggest that it is valid in connection with all kinds of action whenever a generalised mode of thought is appropriate, and that it is likely, to repeat Sherrington's words, 'to teach our sight to grow'.

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PATTERNS OF MUSCLE ACTIVITY IN MOVEMENT AND POSTURE

By W. F. Floyd

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The work described in this paper is based on the observation that electrical potentials can be recorded from active muscles. With modern electronic techniques and using electrodes placed on the skin overlying the muscles concerned, it is possible to measure these potentials, which vary from a few microvolts to a few

millivolts in amplitude and usually have a duration of some 5–20 milliseconds, the shortest of them lasting about a millisecond. Muscle action potentials can be recorded satisfactorily, therefore, with the aid of a cathode-ray or ink-writing oscillograph.

An active muscle produces a succession of action potential waves, as shown in Fig. 1. Many investigators over the past thirty years, including Adrian & Bronk (1929), Lindsley (1935), Jacobson (1938), Gilson & Mills (1941), Hoefer (1941), Ralston *et al.* (1947), Floyd (1952), Floyd & Silver (1950, 1951, 1955), Joseph, Nightingale & Williams (1955), have demonstrated that a relaxed muscle is electrically silent. This is also illustrated in Fig. 1. It has taken a considerable time for this simple fact to be generally accepted by physiologists because it was contrary to classical physiological teaching based on the idea that even a resting muscle possessed 'tone' and was therefore active, (e.g., see Clemmesen, 1951; Ralston & Libet, 1953).

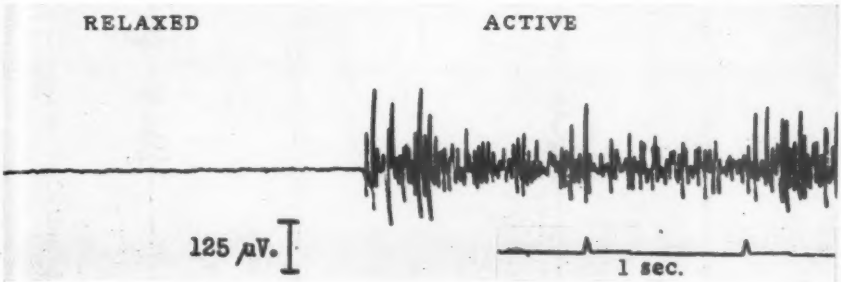

Fig. 1. The first part of the tracing shows the absence of action potentials in the relaxed muscle. When the muscle becomes active, i.e. 'contracts', action potentials can be recorded as shown in the second half of the tracing. The record was obtained from brachialis muscle, the activity shown corresponding to the slight tension required for initiation of flexion of the elbow in the extended arm.

Thus electromyography, as the recording of muscle action potentials is called, provides a convenient tool for the study of muscle activity. Moreover, the method is quantitative, the action potential record being proportional to tension; but the relationship is a statistical one and is not very precise, the agreement between muscle tension at a given length and integrated action potential being within some 10 per cent (e.g., see Inman *et al.*, 1952; Wilkie, 1950). Furthermore, the coefficient of proportionality varies from one person to another, depending on the mass of muscle in proportion to surrounding fat.

Electromyographic recording also provides a method for the study of the relationships of action between different muscles in complex movements involving the co-operation of several muscles. The records illustrated in Fig. 2 show the action potentials associated with relatively simple movements in the upright stance due to spontaneous displacement of the centre of gravity of the body and the corrective muscle activity required for the maintenance of that posture. The record shows that this posture is maintained by intermittent activity of different muscles, corresponding to the small swaying movements of the body. Beevor (1904), from clinical observations, held that this was so, and electromyography proves the correctness of his surmise (see also Hellebrandt, 1938; Floyd & Silver, 1955).

Another important field for the use of electromyographic recording is in the study of skilled movements such as walking, typing or the handling of workshop

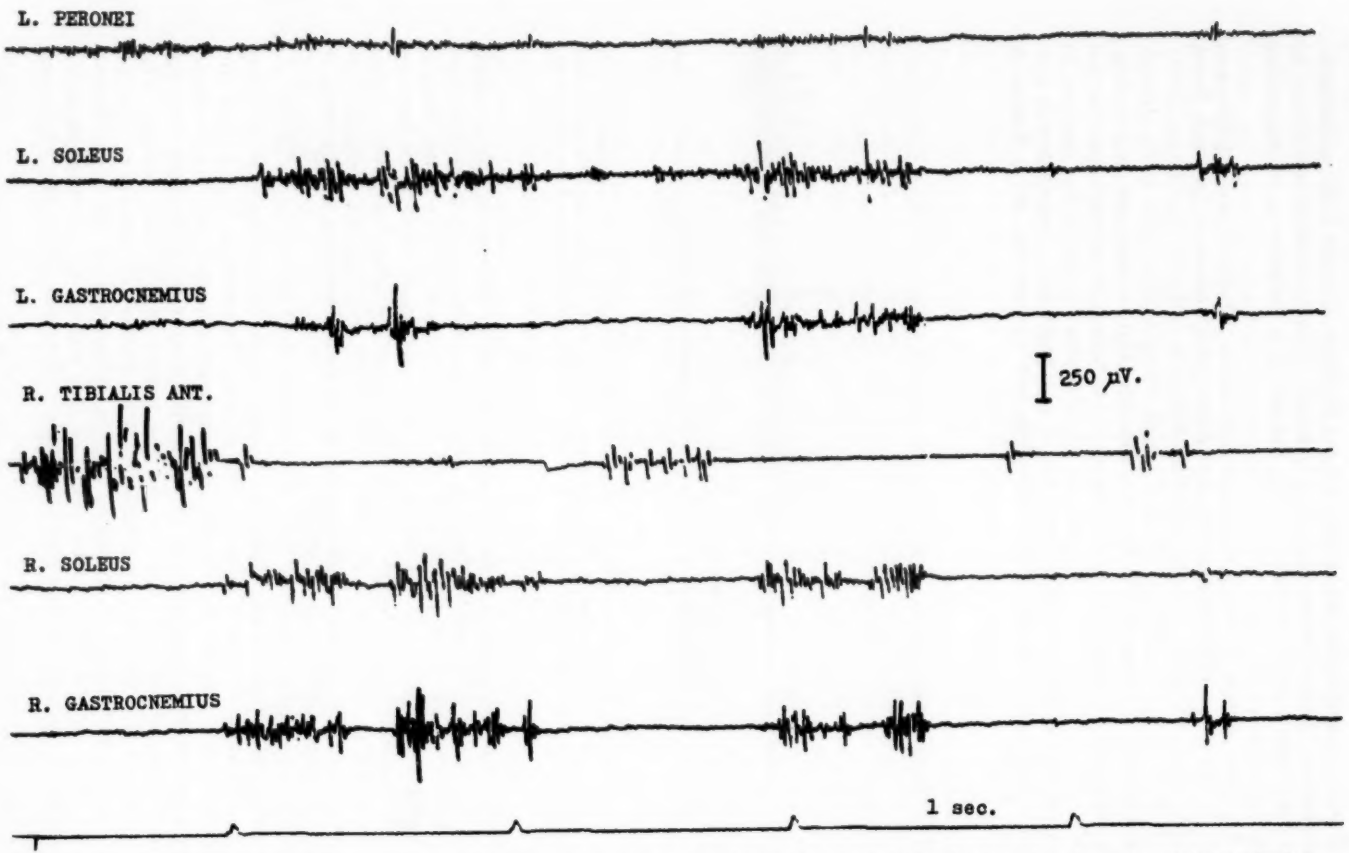

Fig. 2. Electromyograms of action potentials from six different leg muscles, simultaneously recorded, showing interplay of muscle activity required to maintain posture in the upright stance. Each outburst of muscle action helps correct the spontaneous displacements of the centre of gravity of the

tools. In typing, it can be seen from Fig. 3 that there are successive outbursts of muscle action potentials in the flexor muscles of the arm. Each burst of activity corresponds with part of the movement for striking a key. Between the successive bursts from these flexor muscles, the action potential record is seen to be silent, indicating that the muscles are temporarily inactive or relaxed (see also Lundervold, 1951). With increasing fatigue, brought about by the prolonged repetition of the movement, these silent periods disappear progressively, and ultimately the record shows a continuously maintained background of activity with superimposed outbursts corresponding to the repeated movements of striking the key. This situation is illustrated in the second part of the record in Fig. 3 which shows changes in the electromyogram brought about after two minutes' typing by a subject who is untrained and inexpert at typing.

In a study of the acquisition of skill in the use of workshop tools, Person (1958) recorded both mechanical action (forces and displacement) and muscle action

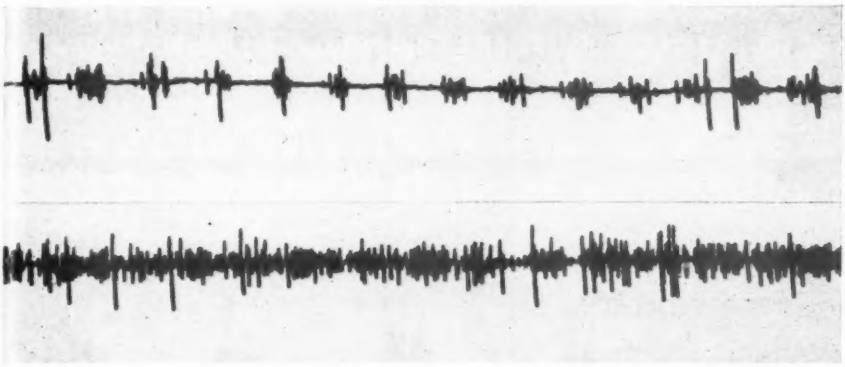

Fig. 3. Recording of electromyogram from flexor muscles in the forearm during typing. The first line shows discrete bursts of activity associated with striking the key. The second line shows changes in the electromyogram brought about by fatigue in a subject untrained and inexpert at typing; there is a background of activity with superimposed outbursts corresponding to repeated striking of the key.

potentials. During filing, for example, he found that the movements are at first uncoordinated, and the electromyograms show fluctuating but continuous muscle activity. With the acquisition of skill the movements become co-ordinated and the electromyograms then consist of burst of action potentials alternating with periods of silence—resembling the electromyogram of the skilled typist. Further, the electromyograms of flexor and extensor muscles show reciprocal action for this task (Fig. 4). The changes in the electromyogram corresponding to the acquisition of skill resemble, in reverse, the changes seen with the onset of fatigue in the performance of a skilled task like typing.

One of the basic muscular problems of physical training is the acquisition of the muscular skills. What does muscle training consist of? What are the differences between movements made by skilled and unskilled performers? It would seem reasonable to expect that the results obtained from the study of skilled movements like typewriting and chiselling might be typical also of muscle skills in the field of physical education. That this is certainly so has been shown recently in a pilot study (hitherto unpublished) by Dr. E. Hamley of the Department of Physiology, Birmingham University, and Dr. H. E. Robson (now of Loughborough College of Physical Education). Hamley and Robson studied the changes in the electromyogram consequent upon training and compared the records obtained from

Fig. 2. Electromyograms of action potentials from six different leg muscles, simultaneously recorded, showing interplay of muscle activity required to maintain posture in the upright stance. Each outburst of muscle action helps correct the spontaneous displacements of the centre of gravity of the

subjects under training with the electromyograms of an Olympic-class gymnast performing the same movements. They found that unskilled performers show:

more activity,
more prolonged activity,
less clear relaxation between phases or cycles of the movements,
greater tendency to fatigue as shown by the continuous action potentials which then occur.

What lessons can the physical educationalist learn from these studies? Perhaps the most important is not to induce premature fatigue (and the continuous muscle activity which accompanies it) by too frequent repetition or by maintaining an excessive speed of performance at too early a stage in training. This question of speed

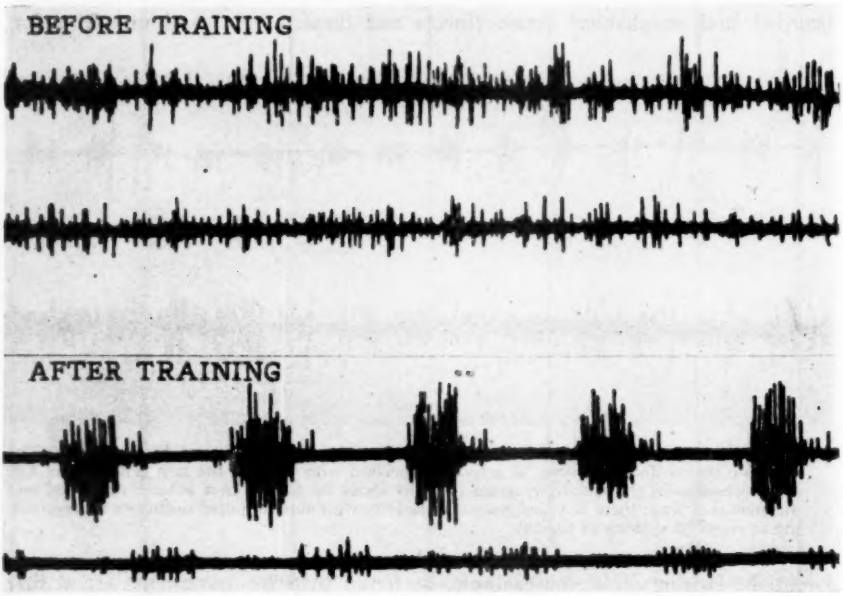

Fig. 4. Electromyograms to show changes with the acquisition of skill in filing. Before training (upper two records), movements are uncoordinated and the action potentials show fluctuating but continuous muscle activity: upper record, triceps; lower record, biceps. After two weeks' training, the electromyograms consist of bursts of action potentials alternating with periods of silence and the flexor and extensor muscles show reciprocal action, i.e. alternate with each other: upper record, triceps; lower record, biceps. (After Person.)

applies with equal force to training and practice at all muscle skills, including, for example, typewriting and piano playing. Occasional, short-lived bursts of speed are acceptable. The maintenance of speed too early in training leads to muscular contractions which may be accompanied by cramp and pain (Lundervold, 1951).

Finally perhaps the electromyogram could be used to accelerate training. With the help of a loudspeaker, the pupil can be supplied with an acoustic feedback of his muscle activity (additional to the in-built nervous mechanisms of proprioception) which may enable him the better to acquire the desired skills. Some research on this question might be worth while.

Thanks are due to my colleagues, Dr. Mary Chennells and Dr. P. H. S. Silver, and to Dr. E. Hamley and Dr. H. E. Robson for permission to draw upon their work.

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THE ICE AGE[1]

by

DR. R. G. WEST

IF WE are to appreciate the natural situation in which man finds himself, and if we are to try and understand the natural factors which control our environment, it is very necessary that we should know in detail what conditions have prevailed on earth during the immediate past.

You may ask questions about, for example, the stability of our islands, about the stability of the sea-level, or about the stability of our climate, all things we may take for granted, but which by changing could affect our livelihood. We can only answer these questions by finding what has happened in the past and from that infer what might happen in the future.

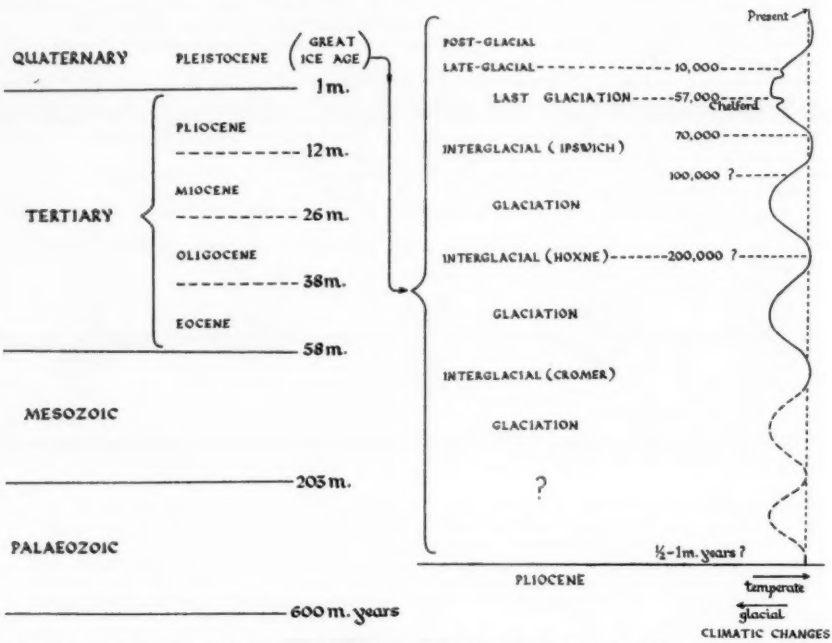


FIG. 1. The geological column. The Pleistocene Epoch, or Ice Age, is subdivided according to climatic change, as is shown schematically on the right.

My own investigations are researches into past conditions of life, especially plant life, climate, and geography in the latest of the geological epochs, the Pleistocene Epoch, a period which covers about the last million years to the present day (see Figure 1). This period is also called the Glacial Epoch or Ice Age, because during it the earth was subjected to repeated climatic changes which resulted in glaciations, when ice spread over a far greater area than it does today. It is also the period in which man as a tool-maker emerged and evolved.

[1] Text of the Darwin Lecture delivered to the York Meeting of the British Association on September 3, 1959.

In 1951, I went to Hoxne,[1] a small village near Diss, on the Norfolk–Suffolk border, to look at some clay deposits formed during the Ice Age and used for making bricks. This deposit had long been famous because here in the late eighteenth century an antiquarian, John Frere, had found in the clay what he called flint weapons, shaped flints later called hand-axes. Frere made two original suggestions about these flint weapons; first, that they were made by men who had not the use of metals, and secondly, that they were made at a time in the distant past before the present landscape was formed. In other words, he suggested that the art of tool-making was a very ancient one. Such an idea about the great antiquity of man was not acceptable in Frere's time, and his discoveries remained disregarded till the middle of the nineteenth century. At about this time, discoveries were made in northern France, in the Somme valley, of similar hand-axes, with the bones of extinct mammals such as the mammoth and the woolly rhinoceros. As a result of these further discoveries it became clear that man as a tool-maker had indeed an

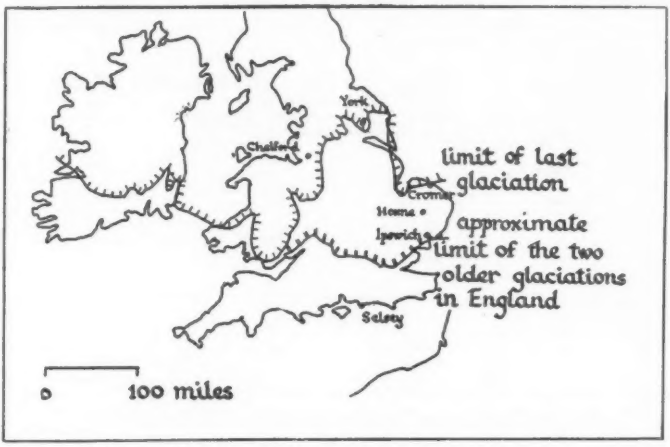


FIG. 2. The limits of the two older glaciations and the Last Glaciation. Also shown are the localities of sites mentioned in the text.

ancient origin. Frere's views were vindicated, and one of the interests of Hoxne is that here the great antiquity of man was demonstrated for the first time.

A second interest of the deposits at Hoxne Brickworks was that here also could be seen deposits formed in an advance of the ice. When an ice sheet advances over the land the ice picks up debris eroded by the ice foot, transports it forwards, and as the ice melts away when the climate improves, leaves it as a disorderly deposit of clay, sand and stones, the proportions of each depending on the material the ice has picked up. Such a deposit has a characteristic appearance and is called till. At Hoxne there is such a till, and its presence shows that at one time a great ice sheet had covered East Anglia. The wide distribution of the kind of till found at Hoxne indicates that the ice of this glaciation spread south in England as far as London and the Severn Valley (Fig. 2). The presence of the flint implements and the till in the same place meant that it should be possible to determine whether the man who made them lived before or after this glaciation, according to whether the implements were under or over the till.

A third interest of Hoxne, besides the flint implements and the evidence of glaciation, was the presence of plant remains in the clay in which were found the implements. If we could find out what plants these were, we should be able to

[1] The most important localities I mention are shown on the map, Fig. 2.

reconstruct the type of vegetation which was present at that time and, because certain vegetation types are characteristic of certain climatic conditions, e.g. tundra vegetation is found in sub-arctic regions and mixed oak forest in temperate regions, so we could get suggestions about the climate from the vegetation.

My task at Hoxne, then, was to find out the exact relation of the different deposits to one another, how each was formed, what the evidence of the plant remains told us about the vegetation and climate, and lastly, how did the hand-axes fit into the picture of climatic and vegetational conditions.

A series of borings by hand auger showed the arrangement of the various deposits at Hoxne (Fig. 3). At the base was blue-grey till laid down from ice. In a deep hollow in this till were a series of sediments deposited in the lake formed after the disappearance of the ice. The thickness of these reached 30–40 feet and their distribution showed that the lake covered several acres. Finally the lake deposits were covered by sands and gravel laid down by ice of a second glaciation. The deposition of these glacial deposits was followed by valley erosion to give the present landscape. We

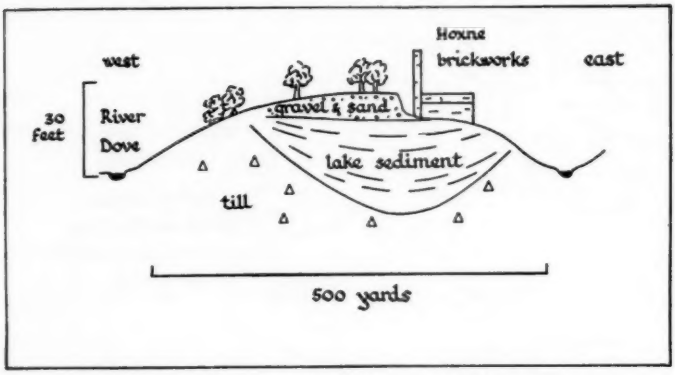


FIG. 3. The stratigraphy of the Pleistocene deposits at Hoxne.

have therefore a series of lake deposits formed in an interval between two glacial episodes.

What were the vegetational and climatic conditions between these glacial episodes? By a study of the plant remains in the lake sediments we can discover much about the conditions of the environment during this interglacial time. First, we can identify leaves, fruits and seeds of plants which have been incorporated into the lake sediments from the surrounding vegetation and so preserved. Secondly, we can use the method of pollen analysis. This method has come to the fore in the last thirty years as a remarkable tool for the investigation of past conditions of plant life, especially in this country as a result of researches carried out by Dr. Godwin and his pupils at the Sub-department of Quaternary Research of the Botany School at Cambridge. Plants liberate into the air minute reproductive cells (Fig. 4), 10 to 100 thousandths of a millimetre in diameter—the pollen grains of higher plants and the spores of lower plants. These pollen grains and spores have very varied shapes and surface patterns which are characteristic of particular families, genera or species of plants, so that the plant from which they come may in many instances be identified. The pollen grains and spores in the air eventually fall to the ground. If they land, say, on a lake surface, they will slowly fall to the bottom and become incorporated in the lake sediment forming. The composition of this rain of pollen and spores depends on the species of plants in the local vegetation, e.g. if we have an oak–hazel forest in the vicinity of the lake, oak and hazel pollen may predominate in the pollen rain. So, from a knowledge of the kinds of pollen

grain found in a sediment we can reconstruct the vegetation around the lake during the time of formation of the sediment.

At Hoxne, for example, analysis of the pollen from samples through the sediments in the deepest part of the lake basin gave the result shown in Fig. 5. At each horizontal level the quantity of pollen of each type is represented on the diagram as a percentage of the total of tree pollen (150 grains counted) identified under the microscope. In the sediment formed at the bottom of the lake, soon after the disappearance of the ice, pollen of herbs such as grasses and sedges is very abundant, as is the pollen of *Hippophaë rhamnoides*, the sea buckthorn; there are a few tree pollen grains, including birch. The pollen assemblage suggests the presence, after the retreat of the ice, of open grassland with small birch copses and with much sea

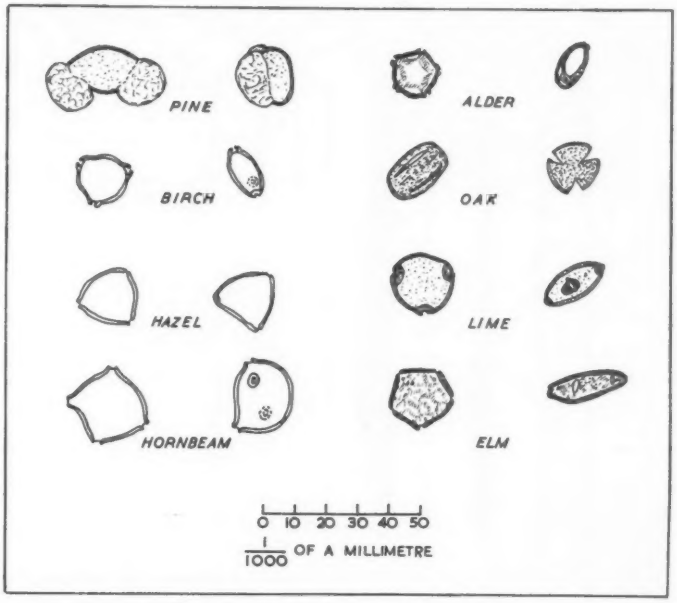


FIG. 4. Pollen grains of various trees.

buckthorn, a shrub liking freshly exposed soils such as would be found on the newly exposed till. This relatively treeless vegetation was succeeded by woodland, first with birch and pine, later with the trees of the deciduous mixed oak forest, the oak, elm, lime, ash, and hazel, such as might be found in this country today had not the forests been destroyed by man's activities. Later, this kind of forest was succeeded by a more coniferous forest, with much pine, silver fir and spruce. Finally, at the top of the sequence the sediments contained the remains of plants indicating relatively treeless vegetation, with few warm-loving temperate trees, but with leaves of plants now found in arctic or alpine areas, such as the dwarf willows and the dwarf birch.

These vegetation types, such as birch–pine forest, or mixed oak forest, are now characteristic of certain climatic belts, so that from these vegetational changes we may distinguish climatic changes. On the improvement of the climate which led to the melting away of the ice at the beginning of the interglacial period, the development of temperate mixed oak forest followed a subarctic treeless phase and a boreal birch–pine phase. The mixed oak forest occupied the time of the climatic optimum of the interglacial. The abundance of ivy, holly and alder at this time suggests that

the climate was oceanic, as these plants have at the present day a wide distribution in such a climate. The deterioration of the climate led to the replacement of the mixed oak forest by coniferous forest, which in turn was replaced by a treeless phase with plants now found in arctic and alpine areas. Presumably this was the cold climate which introduced the glaciation which laid down the sands and gravels covering the interglacial deposits.

The third point, after the investigation of the stratigraphy and palaeobotany of the deposits, was to find the exact position of the hand-axes in the sequence we have

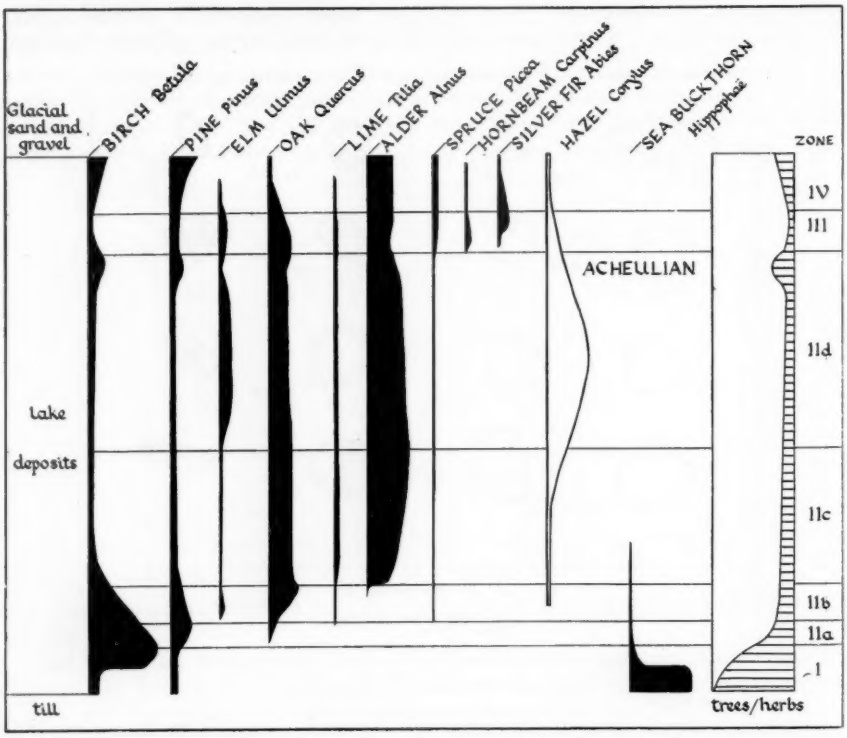


FIG. 5. Schematic pollen diagram through the Hoxne Interglacial deposits.

already described. The hand-axes are of the type known to archaeologists as Acheulian, the name of a lower Palaeolithic culture of hunters. Excavations were made in the marginal parts of the lake deposits, and there we were lucky enough to find flint flakes. We were also fortunate to obtain a hand-axe, found during the working of the brick clay, which had the lake sediment still adhering. The natural tendency on finding such a flint object is to clean it immediately, and this was the only one of those which we saw which had not been so treated.

By analysing the pollen from the sediment adhering to these flint implements, I found it possible to place them in the vegetational sequence discovered by the analysis of the samples from the middle of the lake. They came from the mixed oak forest phase (zone II*d* in Fig. 5). Now in the pollen diagram from this stage there is a temporary fluctuation in the vegetational development. There is deforestation. Certain trees like the elm and oak decline and the pollen of herbs increases; also found here are plants indicative of open ground such as plantains and mugwort.

It is just in and near this phase that the flint objects were found. And also here were found several bone fragments, including part of a thigh-bone of a rhinoceros with tooth-marks, as if it had been chewed by a dog of some sort. Evidently at this time in the interglacial, the men who made the hand-axes were living by the lake-side, throwing their debris into the lake, a natural impulse for anyone living by water. Is it possible that these men—and remember that they were lower Paleolithic and lived at least 100,000 years ago—were responsible for the forest clearance, in the same way that their Neolithic farming successors certainly were 5,000 years ago? We cannot say for certain, as the deforestation might have been accidental, by fire or a shortlived climatic catastrophe, but it is possible.

So much then for the investigations at Hoxne; from them you will see we have a picture of vegetational and climatic changes, and of the activities of man, between two glacial episodes.

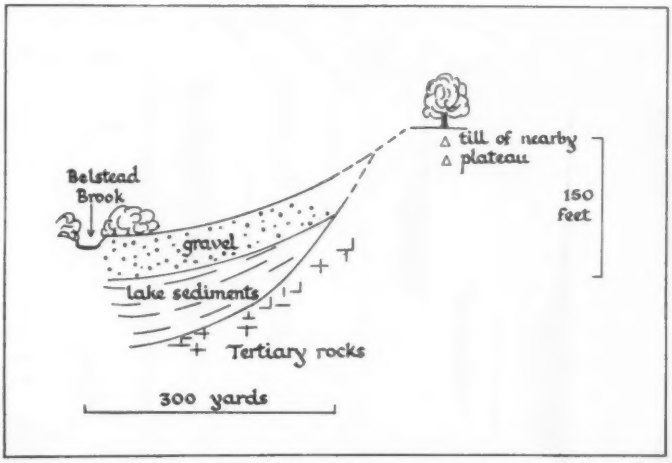


FIG. 6. The stratigraphy of the Pleistocene deposits at Bobbitshole, near Ipswich.

Having finished these investigations, I turned to a lake deposit near Ipswich, discovered by Mr. Spencer of the Ipswich Museum, and there made a similar investigation. The sequence was not so complete as at Hoxne, but showed the beginning of a warm period after a glaciation, with the development of oak–pine–maple forest after an early phase with open vegetation and relatively few trees. The assemblage of plants differed from any at Hoxne, which suggested that this deposit belonged to a different interglacial period. Whether it was older or younger could be decided by the position of the deposit. Fig. 6 shows how it lay in a valley cut in a glacial till which was formed during the glaciation that deposited the upper sands and gravels above the lake sediments at Hoxne. So the interglacial represented near Ipswich must have been later than the Hoxne Interglacial. We have just finished investigating other deposits of the same age at Selsey in Sussex and at Cambridge, and as these cover different parts of the same interglacial, and show overlapping pollen diagrams, it is possible to give a provisional and tentative scheme of vegetational development during this younger interglacial period (Fig. 7).

As at Hoxne, the interglacial shows a vegetational history following a climatic change from cold to warm to cold. At the base after a phase with open vegetation with grasses and other herbs, forest with birch and some pine become dominant. The mixed oak forest trees soon appear, with elm, oak and maple. In contrast to the Hoxne Interglacial, there is not much lime or alder pollen, and another difference

is the presence in this interglacial of a maple now found in central and southern Europe, the Montpellier maple, a bush or small tree with small three-lobed leaves. The pollen of the maple forms a distinct curve in the pollen diagram. After the period with oak–maple–pine vegetation the hornbeam must have become a common tree, for its pollen became very abundant. Finally, the deterioration of the climate is marked by the replacement of the oak and the hornbeam by pine.

Of the plants found in this interglacial, there are some interesting species which are not found in Britain today. These include the firethorn, *Pyracantha coccinea*, the Montpellier maple (*Acer monspessulanum*), and a few water plants, including the water fern, *Salvinia natans*, and a species of *Naias*, *N. minor*. All these are found on the Continent today. Other water plants represented by finds of seeds, though living in this country today, rarely produce seeds as the summers are not warm

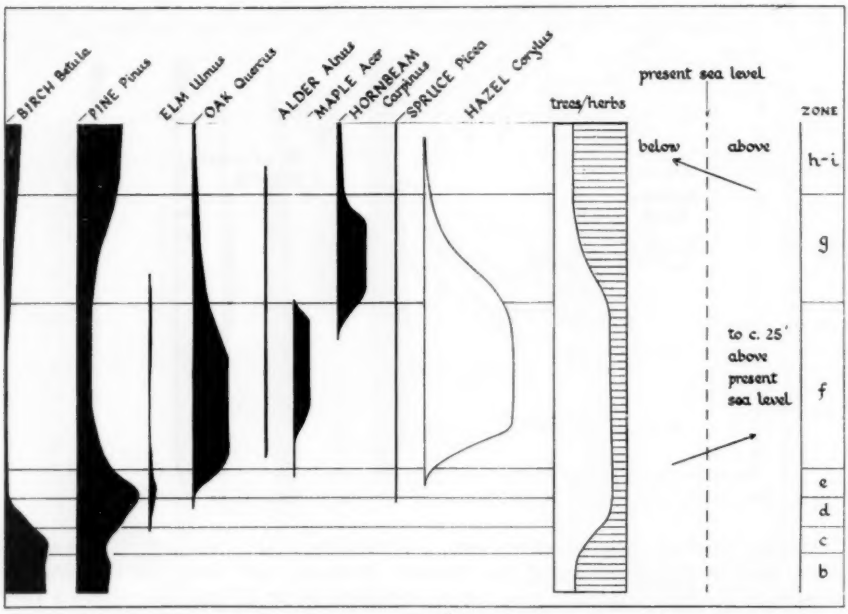


FIG. 7. Provisional schematic pollen diagram through the Last (Ipswichian) Interglacial.

enough. They do so on the Continent, where summers are warmer. Such plants are the water soldier, *Stratiotes aloides*, and the frogbit, *Hydrocharis morsus-ranae*.

The presence of these plants and the abundance of hornbeam, a tree now found in south-east England but with a much wider distribution on the Continent, suggest rather a Continental type of climate for part of this interglacial and indicate that a summer warmth was reached exceeding that of the present day.

At one of the localities of this interglacial I have investigated on the south coast it has been possible to demonstrate another important phenomenon connected with the glacial–interglacial changes of climate. During a glaciation the large increase in the volume of ice results from uptake of atmospheric moisture, which must come eventually from the sea. The world-wide sea-level must therefore fall during a glaciation, perhaps by as much as 300–400 feet. Such a fall would connect our islands with the Continent. Conversely, during a warm interglacial, world-wide sea-level would rise as the ice melted. If it rose to its present height it would again cut us off from the Continent.

In one of these south coast deposits, at Selsey, Sussex, we find estuarine clay and beach shingle overlying freshwater lake deposits which lie at about sea-level. By connecting the change from fresh to estuarine water to the vegetational sequence we can say at what period in the interglacial the sea was rising above present sea-level. In this interglacial the rise was at the beginning of the mixed oak forest zone; the height of the overlying beach shingle indicates that the level rose some twenty-five feet above the present sea-level (see Fig. 7). At another site, where we have found freshwater deposits over marine deposits, we have found evidence that the fall of sea-level was taking place towards the end of the interglacial, during the pine zone.

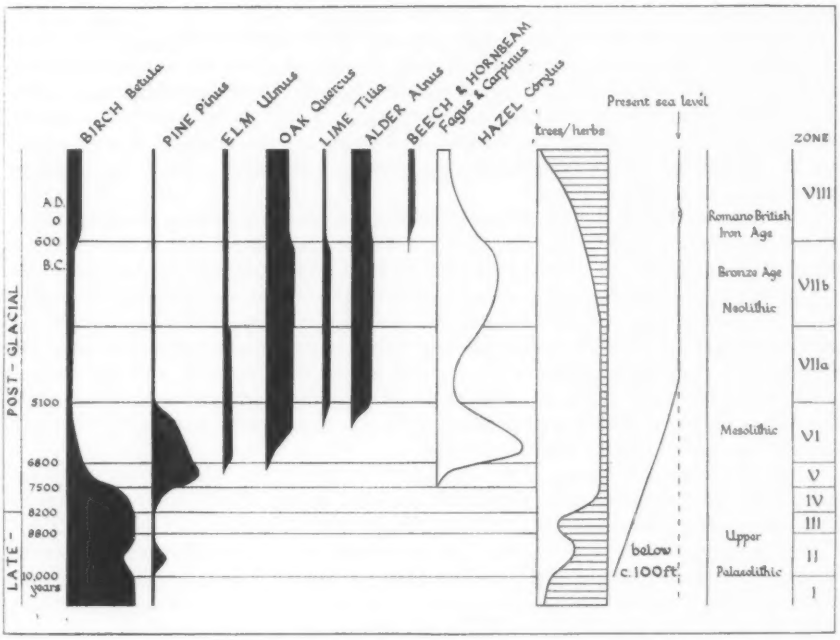


FIG. 8. A scheme of Late- and Post-glacial changes in England.

These interglacial changes of sea-level are obviously of great importance in determining what plants and animals were present in the British Isles during interglacial times. Some plants and animals may survive the glaciation in the area of Britain, especially those now found in arctic or alpine areas. Other warm-loving species must immigrate to our land from the Continent as the climate improves after a glaciation. Whether they will be able to depends on the land connection to the continent and the height of the sea-level.

These younger interglacial deposits in the south of England are covered by thin layers of sand and gravel formed during an arctic climate, not by ice itself, but by the freeze-and-thaw processes of the arctic climate which result in the downhill movement of soil. This arctic climate obtained during a glacial period when ice spread south only as far as the northern limit shown in Fig. 2. This was the last glaciation before our present warm period, so we know that the younger interglacial deposits at Ipswich and on the south coast were formed during the Last (Ipswichian) Interglacial, and those at Hoxne (Hoxnian Interglacial) in the previous interglacial. We do not know the duration of these interglacials in terms of years, but the Last

Glaciation does come within the range of dating by radioactive carbon, and it is known that this glaciation lasted some 60,000 years and ended some 10,000 years ago. The map, Fig. 2, shows that this glaciation was far smaller in extent than the previous ones. In fact, here at York we are on an end-moraine of this glaciation. A lobe of ice extended down the Vale of York, and at one time formed its terminal moraine here.

We have some evidence of conditions during this Last Glaciation. With Dr. Simpson of Manchester University I investigated in the Cheshire Plain at Chelford, south of Manchester, a thin layer of lake mud between two glacial deposits. The plant remains showed the presence at that time of a spruce–pine–birch forest of a kind now seen in northern Finland. A radioactive-carbon dating of a piece of wood from a spruce trunk gave an age of 57,000 years.

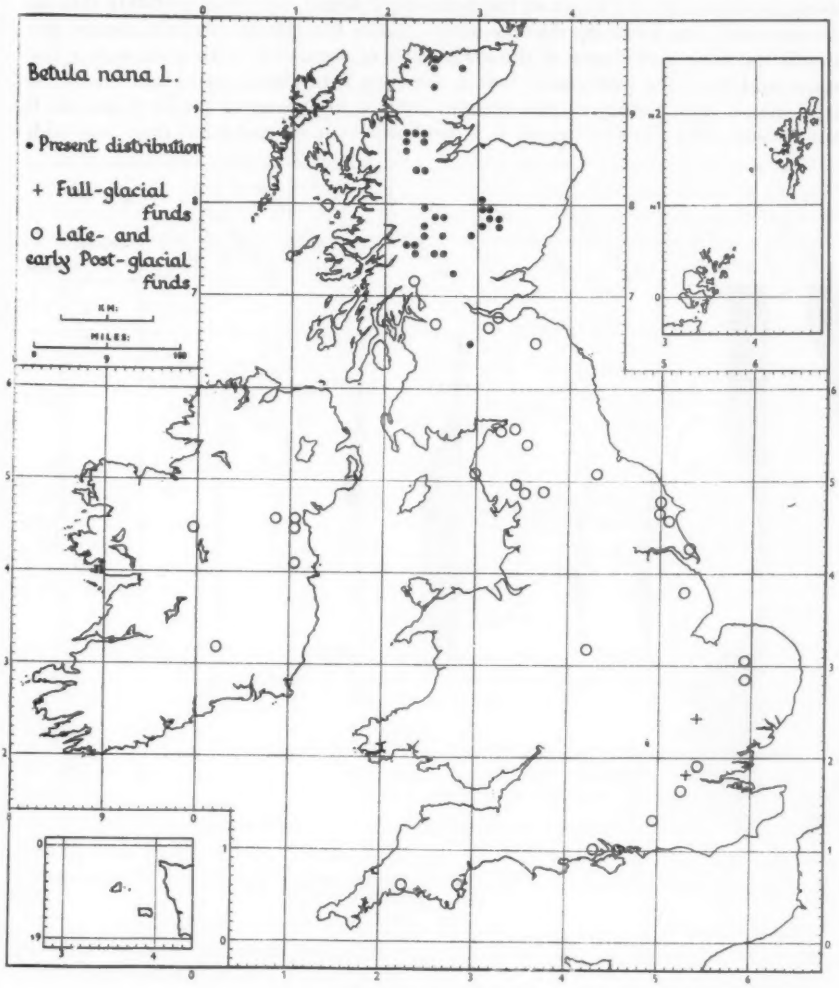
It is probable that the Chelford lake deposits were deposited in a warmer phase of the Last Glaciation, for there are several records of plant remains from much colder parts of the glaciation. They are from deposits near Cambridge and in the Lea Valley in north-east London, and they indicate the presence of grass-tundra with arctic willows and birches. Found with them are the remains of mammoth, woolly rhinoceros, reindeer and lemming, the first two now extinct, the last two today living in tundra regions.

It is estimated that the ice of the Last Glaciation melted away from Britain's mountains about 10,000 years ago. Since that time we have had a series of vegetational changes (Fig. 8) with the development of mixed oak forest, through birch and pine phases, reflecting the improvement of the climate. A study of the vegetational changes suggests that a climatic optimum was reached some five or six thousand years ago, and that since then there has been a slight deterioration to the present day, perhaps a matter of 2°C. mean annual temperature. The rise in sea-level was complete by 3500 B.C., and cut us off from the continent about 6000–7000 B.C. You will realise that it is possible that we are now about two-thirds of the way through an interglacial of climatic change.

These vegetational changes since the Last Glaciation have been investigated far more fully than those of the interglacials and the details I have quoted are taken from the work of Dr. Godwin and his colleagues at Cambridge (Godwin, 1956). Knowing them, we are able to view the history of our present flora and to realise factors which have affected the distribution of our plants. For example, in the case of the few British plants with arctic-alpine distribution, we know through the fossil evidence that such plants were widespread during the glaciation south of the ice limit (during the full-glacial), and also during the period immediately after the glaciation, the Late-glacial period, as shown, for example, by the past and present distribution of the dwarf birch, *Betula nana* (Fig. 9). We can see how their distribution would be affected by the formation of forests—they would be restricted to open mountainous areas. Many of our common weeds—for example, plantain, sorrel, dandelion—have had a similar history. Widespread on the fresh soils resulting from the retreat of the ice and from the movement of soils by freeze-and-thaw action in the glacial climate, their range became limited by the spread of forests. With the advent of agricultural activity in the Neolithic Period, from 3000 to 1500 B.C., they were able to return to the open habitats of cultivated areas.

In looking at the Post-glacial vegetational changes it is very striking how the vegetation changes with the advent of agriculture in this country. As at Hoxne, it is possible to relate archaeological objects to the vegetational history by finding such remains as flint and bone artefacts and pottery stratified into lake deposits or into the peat deposits of bogs, for early habitation sites were frequently close to lakes and rivers. The position of the main archaeological periods in the vegetational sequence is shown in Fig. 8. We see the great effect of Neolithic agriculture on the vegetation in the pollen diagrams. With the advent of Neolithic agriculture, forest

tree pollen decreased and the pollen of weeds of cultivation and open-ground plants increased. From then on, deforestation has continued, till today it is doubtful whether any of our forests are anything but the altered remnants of the Post-glacial forests which once covered a large part of the country.



Distribution maps scheme of the Botanical Society of the British Isles.

FIG. 9. The present distribution of the dwarf birch, *Betula nana* L., with the localities where the plant has been found fossilized in Full-glacial deposits and in Late- and early Post-glacial deposits.

The Post-glacial finds of man are all our own species, *Homo sapiens*. It is possible to say something of man's history in relation to the climatic changes we have described. In this country there is the famous find of part of a skull in gravels of the old Thames at Swanscombe, Kent. The incompleteness of the remains prevents an exact diagnosis of the species, but they show no very distinct differences from the same parts of a *Homo sapiens* skull, apart from an unusual thickness of bone. On the other hand, it is not very different from certain skulls belonging to Neanderthal

man, a race widespread in Europe at the beginning of the Last Glaciation, with a skull characterised by prominent brow ridges, retreating forehead and receding chin. The important point is that together with these Swanscombe bones were found hand-axes and other flint tools, presumably associated with that type of man. Now, at Hoxne, similar types of hand-axe were found, so it was probably this race of man which was living by the lake in the Hoxne Interglacial. In fact, Hoxne gives the earliest known evidence of the association of vegetation with man, dating back to the middle of the interglacial before the Last Interglacial (see Fig. 1).

Of man's later history in this country little is known until the Post-glacial. By comparison with the Continent, it is probable that Neanderthal man was wide-

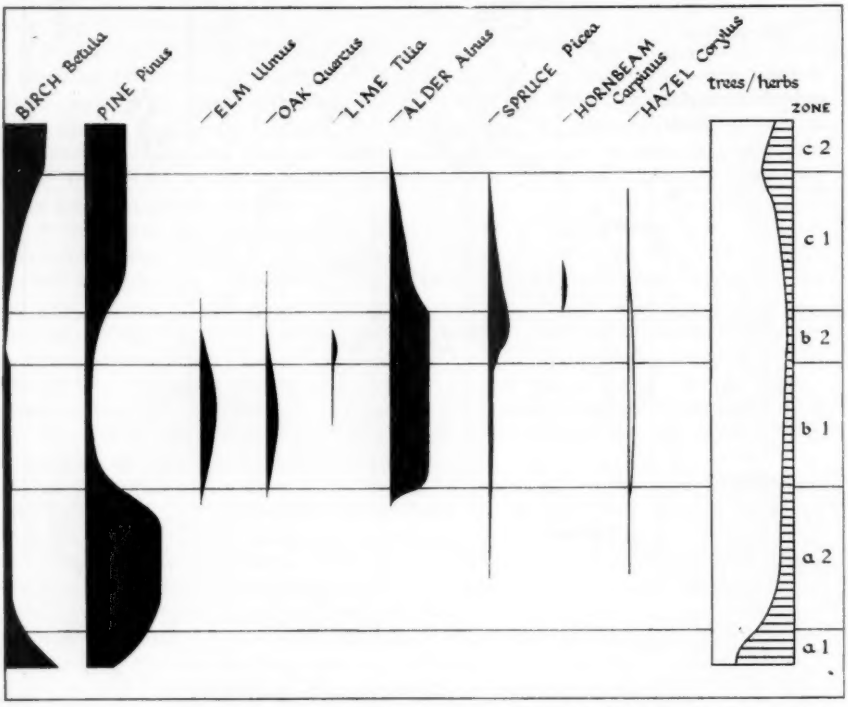


FIG. 10. Schematic pollen diagram through the Cromer Forest Bed (Cromerian Interglacial) (after Duigan)

spread during the end of the Last Interglacial and during the early part of the Last Glaciation. He was then replaced by our own species; why is not known.

We have now considered changes in climate, vegetation and sea-level which we know to have occurred from the present day back to the glaciation which preceded the interglacial at Hoxne. What happened before that?

This glaciation before the Hoxne Interglacial covered a large part of England and it laid down a great thickness of till, especially in East Anglia. Beneath this till on the north-east coast of Norfolk in the Cromer region is the deposit of an old lake containing abundant remains of plants and animals. Dr. Sue Duigan, formerly of the Sub-department of Quaternary Research at Cambridge, has studied the pollen from this layer and her analyses have revealed vegetational changes of the type we associate with an interglacial. She has very kindly allowed me to reproduce the results in Fig. 10. There is an early birch–pine period, suggesting a cold boreal

climate, a middle temperate forest phase with elm, oak, alder, lime and hazel, and an upper boreal phase with pine and birch.

It is remarkable that of the 130 or so species of plants identified by their seeds and fruits, only a small number, about seven, are not native to Britain today, despite the great antiquity of the deposit and the great climatic changes which have occurred since its formation. Such species are *Azolla filiculoides*, a water fern now found in the New World, the spruce and the water chestnut, *Trapa natans*. This is a great contrast to the mammals of the Cromer Forest Bed, which include many species now extinct, including species of elephant, rhinoceros, hippopotamus and deer.

Older than the Cromer Forest Bed we have a series of deposits belonging to the Ice Age which have not yet been investigated in detail. On the Continent deposits earlier than the Cromer Forest Bed are better known, and analysis of plant remains from them indicates similar climatic fluctuations to those we have seen in the inter-

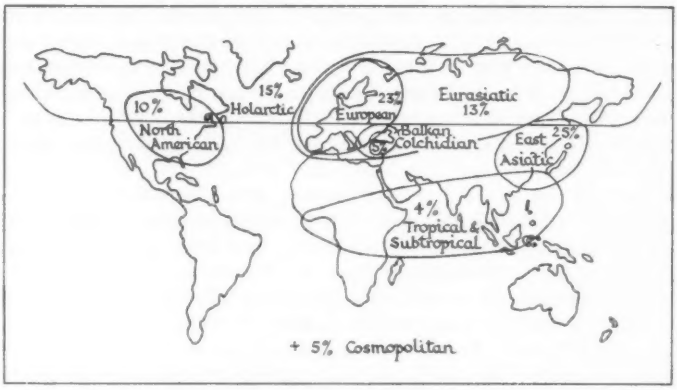


FIG. 11. The present geographical affinities of the Late Pliocene/Early Pleistocene flora in southern Poland (after Szafer, 1954).

glacials. Below the deposits showing the fluctuations, there are lake deposits with a temperate flora, but not showing the marked fluctuations of the glacial/interglacial type. Here we are at the lower boundary of the Ice Age, and as we proceed further back into the geological time scale, the plant remains indicate a slow warming of the climate till in Eocene times, at the beginning of the Tertiary Period, some 30 million years ago, the vegetation in north-west Europe was of a tropical type.

The temperate flora I have mentioned as being found just before the beginning of the Ice Age was by no means the same kind of flora as our present one. The map, Fig. 11, shows the present geographical affinities of plants found fossilized in Poland in the later Pliocene and early Pleistocene, at the beginning of the Ice Age, based on the analyses by Professor Szafer (1954). We see that the flora at that time was composed of many exotic genera and species, notably many now found in eastern North America and eastern Asia.

At the beginning of the Ice Age a great change took place in the European flora and many of these exotic plants became extinct. Their extinction is thought to be related to the oncoming cold of the Ice Age. Clement Reid and Mrs. Reid in 1915 suggested the following explanation. If we look at a map showing the extent of glaciation in the northern hemisphere we can imagine what would happen to the temperate floras pushed south by the oncoming cold. In eastern Asia and north America there are few barriers to southward migration; the mountain chains are

aligned more north to south than east to west. There the Pliocene vegetation could have migrated south and survived in temperate areas while glaciation occurred northwards. On the other hand, in Europe, the Pyrenees and the Alps form barriers to southward migration and so we might expect the extinction of a large part of the warm-loving flora.

As a result we have the fact of the extinction in Europe at the beginning of the Ice Age of a large number of genera and species now confined to the eastern Asian and north American regions. The survival and in some cases the expansion of the other Pliocene geographical elements which make up the Ice Age flora of Europe must be explained by their greater powers of resistance to the climatic fluctuations of the Ice Age. As I mentioned, in Britain very little is known of the vegetation and climatic changes of the early Ice Age before the deposition of the Cromer Forest Bed. We have one or two samples containing the pollen of such exotic trees as the north American hemlock spruce and the Caucasian wingnut, as well as other forest trees, like oak, elm, and alder, genera which belong to our present flora. It seems that some of these Pliocene exotic species persisted into the Ice Age for a short while, as did the New World water fern, *Azolla filiculoides*, found in the Cromer and Hoxne Interglacials. This early part of the Ice Age is obviously a very important time for the evolution of our flora, and later this year we are carrying out a deep boring into the deposits to get samples which should, after the kind of study made at Hoxne, reveal the climatic and vegetational changes earlier than the Cromer Forest Bed.

This then is the background of environment to the evolution of our species. A fluctuating one, of changing sea-level, climate and vegetation, changes which have been continuous since the beginning of the Ice Age. It seems possible that we are now in an interglacial period, already past the climatic optimum. We can imagine what would happen if there was another glaciation. The sea-level would go down as the ice built up and the climate deteriorated. Perhaps we should have to look for methods of ice control. But in spite of what we know of the past history of the Ice Age, the cause of glaciation is as yet unknown. It is clearly an important problem to be solved.

On the other hand, if we are at the end of the Ice Age, should the Greenland and Antarctic ice-caps melt, all the world's maritime cities would be flooded by the consequent rise in sea-level. We are fortunate indeed to be living in a relatively stable part of the Ice Age.

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THE WORK OF ALEXANDER VON HUMBOLDT AND CARL RITTER: A CENTENARY ADDRESS[1]

by

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TO GEOGRAPHERS, 1959 is a centenary year of the first order. The two great initiators of scientific geography, Alexander von Humboldt and Carl Ritter, both died one hundred years ago, Humboldt on May 6, 1859, when he was almost 90, and Ritter on August 28, 1859, at the age of 80.

The life-work of each had at that time long since passed its zenith. In solitary grandeur, Humboldt, the last universalist of the natural sciences, lived on into a period in which specialisation in physical, biological and earth sciences became the order of the day. Carl Ritter's lofty moral and teleological ideas concerning the place of mankind and of the world's peoples in relation to the earth as a whole were supplanted by the positivistic philosophy that in the middle of the nineteenth century gained a firm footing even in the sciences concerned with man. Thus, we are wont to regard the year in which these Dioscuri of geography died as the termination point of our science's classical period. A. von Humboldt we see as the creator of modern physical and biological geography, and C. Ritter as the creator of historical and cultural geography.

In the same year, 1859, Charles Darwin's *The Origin of Species* was published; it applied the theory of evolution to general biology, but later kindled new ideas also in the fields of biogeography, sociology, ethnology and human geography. Some years earlier, in 1851, young Elisée Reclus, who was to become the founder of modern geography in France, hastened to Berlin to study with Carl Ritter, then 72 years old, whose idealistic philosophy became the keynote of Reclus' *Géographie Universelle*. In 1858 and 1859 two men were born in Germany who were to play a significant role in the development of geography as a modern science, Albrecht Penck and Alfred Hettner. The latter could later boast of being the first to have studied geography as a special science.

It is a great honour for me that I have been asked to speak to you of two such great men of classical geography, of their lives, their research and their position in the intellectual history of the eighteenth and nineteenth centuries. During the years of Alexander von Humboldt's childhood, a new era of discovery began, this time a pronounced scientific era of discovery, an era in large part characterised by Early Romanticism's attitude toward nature. In 1769, the year of Humboldt's birth, James Cook had left on the first of his three expeditions to the South Seas. Later, in his student days, Humboldt was so fortunate as to make friends with George Forster, who had accompanied his father on Cook's second circumnavigation of the globe. Both young men were pioneers of liberalism, full of enthusiasm for the young American nation's ideal of freedom and for the call that demanded social justice in a new Europe. Together they travelled from England to Paris in 1790 to witness the celebrations in honour of the French Revolution's

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first anniversary. Forster subsequently suffered the tragic death of an uncompromising revolutionary, while Humboldt later modified his political position. But on their travels together to the Rhine, the Netherlands and England, Humboldt was greatly inspired by Forster, who had done extensive research in the fields of anthropology, history, literature and political economy and, young as he was, had with great imagination and romantic ardour written travelogues describing strange lands and peoples. This particularly roused Humboldt's interest in the tropical regions.

Alexander von Humboldt

It was probably to Humboldt's advantage, however, that he had to wait nine years before his ardent desire to be off to foreign lands was fulfilled. In the meantime he could complete his scientific and philosophical education. Together with Leopold von Buch, he studied mineralogy and mining under Abraham Gottlob Werner at Freiberg. Subsequently, from 1792 to 1795, as assessor, and soon as director, of mines in the Prussian Principality of Bayreuth, in the Franconian Forest, Humboldt gained practical mining experience that was to be of great value to him all his life. He began a series of journeys in the Alps, to Galicia and Silesia by way of Vienna, through northern Italy and in Switzerland. In Geneva he met such renowned natural scientists as Horace Bénédict de Saussure, the initiator of scientific mountaineering, famous for having climbed Mont Blanc, as well as Jean

André de Luc and Raoul P. Pictet. In Italy he visited Alessandro Volta, for he had become fascinated by the problems of animal electricity, discovered in 1789 through Galvani's experiments with frogs' legs.

The young Humboldt was intensely interested in the living organism in relation to environment, or as we should say today in physiology and ecology. On a trip from Göttingen to the Rhine he studied the basalt formations at Unkelstein near Bonn, stimulated by the controversy of the Plutonist and Neptunists, also examining the basalt flora. He supplemented his *Flora Fribergensis Subterranea*, based on observations in the Freiberg mines with aphorisms on the chemical physiology of plants and endeavoured to define 'vital force', a concept introduced by the French school of Montpellier, as 'an unknown cause which hinders the elements in following their original power of attraction'.

The controversy among physicists concerning the nature and the cause of animal electricity impelled Humboldt to make repeated experiments in this field, about 4,000 in all, some of them on his own body. The observation of nature, he believed, should be supplemented by experiment. He came to regard nature as 'the immeasurable laboratory', and the organism as 'an aggregate of material substances' and 'a complexus of organs which constitute the animal machine'. These experiments, on which, in 1797, he published a two-volume work entitled *Experiments with Irritated Muscle and Nerve Fibres*, did not, it is true, solve the problem, but in the course of them Humboldt turned his back on vitalism. Instead of an unknown cause he now assumed an interplay of substances and forces. As a result he formed the concept of Vital Chemistry from the combination of physiology, chemistry and mechanics. He took over from the physician John Brown and his *Elementae Medicinae* the idea that the common cause of all vital action is excitability.

It was of great significance that in preparation for his extensive travels Humboldt came into close contact with the poets and natural philosophers of Jena and Weimar. Because of his many-sided interests in the field of natural sciences, he felt drawn particularly to Goethe, who admired Humboldt for his good common sense, his realistic and concrete way of thinking, and the great diversity of his knowledge, which, as Goethe said, 'flows as from a fountain with many spouts'. Humboldt was inspired by Goethe particularly in morphology, and his ideas on the physiognomy of plants are Goethe's form theory applied to the multiformity of nature.

Philosophically, Humboldt was bound to come into close contact with the idealistic and transcendental natural philosophy of Schelling. As a pioneer of scientific thought in the field of natural sciences, Humboldt could not avoid problems concerning the boundary line between natural and spiritual phenomena or between reality and ideality. To Schelling, nature was only objectified spirit. Nature and spirit are identical, he said, and the underlying identity is the Absolute, the Divine. In contrast to this Humboldt was consciously and emphatically an empiricist, drawing his conclusions from observations, measurements, experiments and calculations. It was this open-minded empiricism and its application to the great range of natural phenomena which caused Humboldt to become the pole-star of upward-striving research in earth sciences.

After ten years of 'apprenticeship', so to speak, there opened for Humboldt the prospect of entering on the long-desired second period of his life, the five years of his 'wanderings'. After his mother's death in 1796 he was able to dispose at will of his considerable fortune. In Paris, which in that day and age was the world's great centre for the natural sciences, and where his brother Wilhelm was already associating with an intellectual élite, Alexander von Humboldt got to know the great natural scientists of his time, Laplace and Lagrange, Cuvier and Geoffrey St. Hilaire, Lavoisier and Jussieu.

In Paris, plans were being made for extensive expeditions by ship, in which Humboldt was to take part. It was a time of war, however, and many such preparations were frustrated. Humboldt nevertheless found Aimé Bonpland, the botanist and anatomist who was to be his faithful companion in all his travels, then, until his tragic emigration to Paraguay, the elaborator of the botanical collections. Instead of travelling to Egypt and thence to India, as originally planned, both went to Spain, where Humboldt dispelled the King's mistrust by his enthusiasm, and gained active support as well as permission to travel in the Spanish colonies in America. From the same coast, though not the same harbour, as Christopher Columbus some 300 years earlier, Humboldt in 1799 set sail for the same part of the world, the countries bordering on the Caribbean Sea.

The once delicate boy, whom only work in the Franconian mines had steeled, would hardly have been thought capable of the endurance that Humboldt now showed in carrying out his enthusiastic plans. Eagerly interested in everything, in nature as in people, he roamed the hot lowlands and the mountainous regions of tropical America, observing, sketching, measuring and collecting. He climbed the snow-covered mountains under the hot equatorial sun, and on Mount Chimborazo, which was at that time considered to be the world's highest peak, achieved a world altitude record that remained unbroken till 1838. Not according to any previous plan but rather through a series of contingencies that determined his routes of travel, Humboldt became the first explorer of nature in tropical mountain areas, if by nature is understood the association of such phenomena as structure, climate, flora, fauna and the general character of the land as a habitat of man.

We cannot be concerned here with following the routes of Humboldt's travel in America. We must turn our attention to the contribution his observations made to scientific progress. Humboldt brought back more material than any explorer before him, including a herbarium with thousands of new species. Elaborating this material employed a staff of scholars and artists for twenty years, and grew into a bigger scientific project than any previously undertaken. More than thirty richly illustrated volumes, folio and quarto, some written by himself, others by his assistants, constitute the expedition's report.

During the twenty years of this scientific harvesting—the third period of his life's work—Humboldt was at the height of his fame. With the exception of Napoleon, no other European was more famous. No other associated, in person or by correspondence, with so many scientists, artists, authors and politicians. Universities and Academies of many countries vied with each other in heaping honours upon him. When Humboldt returned from America, the philosopher Schelling called him a second Columbus. Darwin extolled him as the greatest scientific traveller of all time. The Paris Academy had a commemorative medal made for 'the new Aristotle', and both Latin America and North America celebrated him as a great pioneer of civic freedom and of scientific independence.

The climax of Humboldt's career was reached between 1827 and 1829. He had spent a large part of his fortune on the trip, financing it entirely by himself, and the rest on the organisation and publication of the monumental report. Therefore, at the age of 60 he began the fourth period of his life, giving in to his brother's pleas and accepting the royal invitation to return to Berlin as Chamberlain and permanent court advisor to the King of Prussia.

At that time he conceived his *Cosmos*, to be, as expressed in its sub-title, 'a general survey of the physical phenomena of the universe'. He decided to present his thoughts on the universe in the form of public lectures, even though he had never been a university teacher, and his only experience in lecturing had been before small groups of academy scholars or in private circles. His 'Cosmos' lectures drew great crowds, high and low listening to them with growing enthusiasm.

During the last thirty years of his life, Humboldt was occupied almost entirely with writing his great work *Cosmos*, though frequently interrupted by the representative duties of his office at home and abroad. The first volume of *Cosmos* appeared in 1845; the fourth volume was concluded shortly before he died in his 90th year. In *Cosmos* Humboldt endeavoured to assemble all the knowledge of his day concerning the universe, the earth as a cosmic body, the atmosphere, the sea, and, by no means last of all, the world of living organisms. *Cosmos* is an aesthetic portrayal of all this, written in a lively style, and supplemented by an immense number of scholarly annotations.

The epoch of erudite societies had begun: in 1828 the Geographical Society of Berlin was established, the first of its kind except for the Société de Géographie de Paris, and this was followed by the establishment of the Royal Geographical Society in London in 1830, one year before the British Association for the Advancement of Science came into being, The creation of the Berlin society was largely due to the efforts of Carl Ritter, who for 21 years was its president.

In 1829, the third year after Humboldt's return, another great wish of his came true, an exploration trip into Asia at the invitation of the Tsar. For nine months Humboldt travelled from the Volga across the Ural and the Altai Mountains to the boundary of the Chinese Empire, returning by way of the Caspian Sea. To Humboldt this journey was the culminating point of his life.

Few people today are aware how greatly Humboldt influenced the learning of his day, how many facts and methods that are a matter of course to geography today may be traced to him. Nor is it widely known how, on the other hand, his life mirrored the intellectual, cultural social, economic and political conditions of Europe in his century.

Let us try to estimate his life's work in terms of natural science. His point of departure lay in the upsurge of exact and descriptive sciences that had taken place during the eighteenth century. Instruments had been invented, or improved, for measuring temperature, atmospheric pressure, humidity, earth magnetism and atmospheric electricity. These techniques first made possible a physical survey of wide areas, and atmospheric, hydrologic and telluric geophysics. Through the examination of minerals, rocks and their stratification, sagaciously interpreted by James Hutton in Scotland, there was being developed the science of geology, the systematics of which were provided by Abraham Gottlob Werner. Charles Augustin de Coulomb had, by experiments and calculations, so far improved scientific understanding of magnetism that world-wide measurements of the earth's magnetism were in urgent demand. In the field of metereology the Societas Meteorologica Palatina at Mannheim had in 1780 begun to set up an observation network in different parts of Europe, thereby paving the way for the development of atmospheric physics into climatology. Alexander von Humboldt recognised the full scope of the task and fixed a goal by carrying measurement research into the lower latitudes and—inspired by Saussure's work in the Alps—into the elevations of tropical mountains.

Biological research, too, was soon faced with new tasks. Karl von Linné had systematised the manifold forms of life that had become known in Europe. Moreover, some first attempts in the direction of the science of plant distribution had been made. Humboldt bridged the gap between this and atmospheric physics, seeking to understand the geographical distribution of plants according to zones of temperature and gradations of altitude.

The epoch-making effects of Humboldt's geographical research are in large part due to his physiognomic perception, not only through his talent for observation, but equally his ability for graphic representation of the insight gained. At the top of instructions he wrote for the Mining School of Mexico stood the motto: 'The senses are less stimulated by what the ear takes in than by what we see with our

eyes.' His graphic representation of many kinds of natural phenomena had the most fruitful influence on the sciences.

Humboldt originated the brilliant idea of using isotherms to mark the distribution of temperature on the earth's surface. In this way, a confusing array of temperature figures from both the Old World and the New was all at once coordinated in a single graphic representation, making it possible to recognise why the decrease of temperature towards the Poles is not everywhere the same. All representations of spatial gradations in climatology and oceanography today are based on this innovation. The simplest facts of orography, now presented in every school atlas, became depictable only after Humboldt on his travels took systematic measurements of altitudes and converted them into profiles.

Before Humboldt, Laplace had concerned himself theoretically with average altitudes of the continents and with average depths of the sea. Humboldt, however, made it clear that these averages cannot be mathematically determined. By comparing the surface covered by mountains, plateaux and lowlands, he arrived at an average altitude of only a thousand feet, whereas Laplace had claimed it to be three times that much. By Humboldt's figure it became apparent that the average land altitude is much less than the average sea depth.

During his travels in America, he was also constantly determining astronomical positions and measuring the earth's magnetism. It is important to remember that at the time of Humboldt's trip, our knowledge of the position of many regions of the earth was still very inaccurate. The relative locations of Mexico and Cuba, for instance, diverge by some 300 miles from what they were considered to be at that time. Throughout his life, Humboldt was intensely interested in the earth's magnetism. In his youth he discovered in the Franconian mountains the magnetic anomalies caused by eruptive rock. The French geodesist Jean Charles Borda equipped him with an inclination compass for his big trip, and he took 124 readings to find an answer to a question typical of his world-wide vision: What are the laws governing the varying intensity of magnetic force at different distances from the magnetic equator?

A large part of Humboldt's research was devoted to geology, a science still in its infancy when he was a student at Freiberg. Like Goethe and Werner, Humboldt was at first a Neptunist, in contrast to the plutonistic doctrine of James Hutton. But his studies on the volcanoes of Tenerife, Mexico and the Andes convinced him that the eruptive rocks had been formed by igneous intrusion or effusion, so that he learned to distinguish sharply between eruptive and sedimentary rocks. Humboldt became an advocate of the magmatic theory in volcanism. He discovered a causal relationship between vulcanism, tectonic movements and earthquakes, and sought to trace back everything to a uniform inner force.

As for the organic world, the main object of his research was plant distribution, which he recognised as the most important factor determining the character of landscapes. He classified these landscapes into types, such as the savanna, the steppe, the rain forest or the paramo. One reason for the far-reaching effects of his phytogeographical works published in 1807 and 1817 was that they were so impressively illustrated with profile diagrams. Humboldt's three-dimensional concept of the earth's plant cover and landscape types was a stroke of genius.

In addition he developed ideas concerning plant physiognomy, the point of departure for the study of the life forms of plants. This research bore fruit only after Humboldt's death, when the spread of the doctrine of evolution resulted in the differentiation between the adaptational characteristics and the organisational characteristics of plants.

As a universal earth scientist, Humboldt by no means remained limited to research in fields of natural science. He was productive in the social and economic sciences as well but in these fields also he retained his empirical and practical

approach. The theoretical and abstracting systems of thought in the field of economics, as taught by Adam Smith, Thomas R. Malthus, David Ricardo and Heinrich von Thünen had no attraction for him.

Even as a young man Humboldt, occupied with practical work in the mining industry, achieved something remarkable. He built in the small town of Steben the first school of mining in Germany, quite according to his own plans and, at first, at his own expense. From Peru he sent guano to Europe in order to have it chemically analysed for its value as fertiliser, an effort that bore fruit thirty years later, when systematic exportation of guano began.

What directly occasioned his trip to Asia in 1829 was the fact that the Russian Minister of Finance, Cancrin, had requested his opinion on whether it might be possible to introduce a platinum currency on the basis of the platinum deposits discovered in the Ural Mountains. Humboldt's answer in the negative later proved to be correct.

He was fascinated equally by the study of the world's gold deposits and the role of gold in the world's economic systems. In 1841 he wrote a treatise 'On fluctuations in the production of gold in consideration of the problems of political economy'. This treatise was probably the first attempt to substantiate an economic discourse by world-wide statistics.

A masterpiece pointing to the future was his five-volume work on Mexico, which included an atlas and was later followed by two volumes on Cuba. Behind the title, 'Essai politique sur le Royaume de la Nouvelle-Espagne', is concealed a learned economic, social and political exposition based on statistical material and encompassing the physical character, population and its migrations, racial and social classes, agriculture, mining and fishing, trade, industry, commerce, and finally, the national budget and the national defence system of Spain's colonial realm. This was probably the first work of its kind in world literature. Because of its scientific and comparative approach, it is still of value to us after 150 years. In fact, the approach might almost be called modern in such spheres as cultivation of the soil, the origin of cultivated plants and domesticated animals, the pulque industry (which produces Mexico's national beverage), and artificial irrigation. Humboldt's suggestion that American varieties of potatoes be used to improve European ones has finally been followed in our day through scientific plant breeding.

Though in Mexico he, as a mining expert, was in the then richest mining country of the world, Humboldt was realistic enough to calculate that the produce of Mexico's agriculture exceeded that of all its gold and silver mines by one-third. This fact he found encouraging, since he believed the produce of the soil to be the only firm foundation for permanent prosperity. Although he dedicated the work to King Charles IV of Spain, he did not hesitate to point out frankly in it that conditions under the mercantile system of the late colonial period were untenable. He actually paved the way towards Mexico's independence, for which that country thanked him by bestowing on him its highest decoration of honour.

Similarly his work on Cuba was the first scientific analysis of a tropical plantation-colony. Humboldt saw this country just at the time when—after the negroes' revolution in Haiti—the sugar cane industry and the importation of slaves were expanding most rapidly. In this case, too, he called attention to the infeasibility of a colonial economic system and by his arguments against slavery helped to prepare the way for emancipation.

Moreover the historicism of the early nineteenth century, the rise of the historical movement in the mental and moral sciences of the classicistic period, had an effect on Humboldt's life's work. In America he had become acquainted with the ancient civilisations of Colombia, Peru and Mexico, which obviously contradicted the theory, still defended by Friedrich List, of civilisation's three steps (hunters, nomads and agriculturists), since in those regions agriculture had developed

without any livestock-breeding. These observations of Humboldt were only belatedly accepted in the sphere of cultural history.

Volume 18 of his work, reporting on his American travels, consisted of a comprehensive study called 'Critical Enquiry into Historical Development of Geographical Knowledge Concerning the New World, etc.'. This created such a sensation that he was again and again called upon to act as arbitrator in disputes between Latin American countries concerning their frontiers.

In spite of these prodigious accomplishments, there was no lack of criticism, in particular towards the end of Humboldt's life and after his death. To understand the reasons for this, it is necessary to realise that around the time of Humboldt's death universality in learning had begun to be so eclipsed by specialisation in the natural sciences. We find, for example, that in the big biography of 1872 the young historian Dove classified Humboldt merely as the 'polyhistorian of the natural sciences'.

The exponents of the individual scientific fields are not to be blamed if in retrospect they deplore that their special science was not as much furthered by the genius of Humboldt as it might have been had he been less universal. Humboldt would without doubt have been an excellent successor to his brother as minister of cultural affairs, or an outstanding administrator for the Prussian mines or, just as surely, a brilliant university professor, or a pioneer in physiological research. But in the idealistic and romantic intellectual world of his youth he saw his calling in a much broader framework. Scientifically, this meant the illumination of nature's mysteries in free research throughout the whole wide world. Intellectually, it meant fostering humanism and liberalism. Socially, it meant advocating human rights, civic freedom and social justice. Franz Schnabel, interpreter of German nineteenth-century history, has evaluated Humboldt's historical position as follows: 'At the turning-point from universalism to empiricism stands the figure of Alexander von Humboldt in lonely grandeur'. 'It was his destiny to unite in himself two successive eras and therefore to be open to attack from two sides; the philosophers and poets reproached him for being too empirical, and believers in rising specialisation took amiss his tendency to be universal'.

But let us remember Humboldt's humane as well as his scientific mission. Even though later in life he no longer believed in the possibility of realising his ideals for humanity and was forced to live a life of compromise, nevertheless until his death he spent his energies in this direction. From the report on his travels it can be seen how indignant he was at the mistreatment of the Indians, at the atrocities committed during the conquest of Peru and Mexico, and at the slave markets he saw at Cumana. When, finally, he got to know those aspects of slavery on Cuba's plantations which defied all feelings of humanity, he openly joined the anti-slavery movement proceeding from Great Britain. In his treatise on Cuba he speaks in detail of 'this greatest of all evils that have ever befallen mankind'. But his approach was not only theoretical and moralising; he also made practical suggestions for decreasing slavery step by step until it could be generally abolished, basing these proposals on what seemed to him feasible in terms of the island's social and economic structure. 'Someday it will be difficult to believe,' he wrote, 'that previous to 1826 no island of the Antilles had a law preventing children at a delicate age to be sold and separated from their parents, nor a law prohibiting the branding of negroes with hot irons for the sole purpose of making it easier to recognise this human livestock.'

When in 1856 an English edition of his work on Cuba was published in New York with the entire seventh chapter on slavery arbitrarily left out, he raised a public hue and cry, even to the extent of placing advertisements in New York newspapers, since this very chapter was of far greater importance to him than all his painstakingly collected material on astronomy, magnetism and statistics. As an

'unyielding defender of the greatest possible freedom in the expression of opinion,' he said, 'I believe myself justified in demanding that in the free States of the American continent it be possible to read what has, in the Spanish translation, been allowed to circulate ever since the first year of publication.' In the history of human rights, Humboldt may rank next to the Indians' apostle, Las Casas.

To complete the picture of Alexander von Humboldt's personality, a word must still be said about his attitude towards religion. A scientific empiricist, to whom even the human mind seemed a world inaccessible to research, he never expressed an opinion on primal origins of the world or man's ultimate destiny. In any case, he was not a practising member of any church. However, his high aesthetic sense, his awe for everything great and good, his recognition of the glorious order and harmony of nature in its entirety—all this probably let him believe that this world cannot be a product of pure chance. At one point in his *Cosmos*, when speaking of man's sensations when contemplating nature, he calls nature 'God's sublime realm'.

Carl Ritter's work was not, as Humboldt's, rooted in the natural-scientific research of the age of rationalism, but in eighteenth-century concepts on mankind, the earth's peoples and their history in relation to terrestrial environment. Even before reaching his seventeenth year—starting, in fact, with his sixth—Ritter was influenced by the educationalists Ch. G. Salzmann and J. Ch. Guts Muths, since in these years (1784–95) he attended the Philanthropinum Schnepfenthal in Thuringia. Ritter himself became a teacher and from 1798 to 1815 was employed as tutor in the family of the banker Bethmann, in Frankfort. His travels with the Bethmann boys through Germany, Switzerland and Italy, as well as his sojourns with them in the university towns of Geneva and Göttingen gave him ample opportunity to extend his knowledge of languages and broaden his understanding of literature, history and the natural sciences, especially geography.

His Swiss travels in 1807 were of decisive importance to him. He responded strongly to the wonders of nature and the beauties of landscape. He became closely acquainted with Pestalozzi and his collaborators at Iferten. Pestalozzi's ideas on reforming education inspired Ritter's ideas about geographical teaching and about geographical science as a task of education and culture.

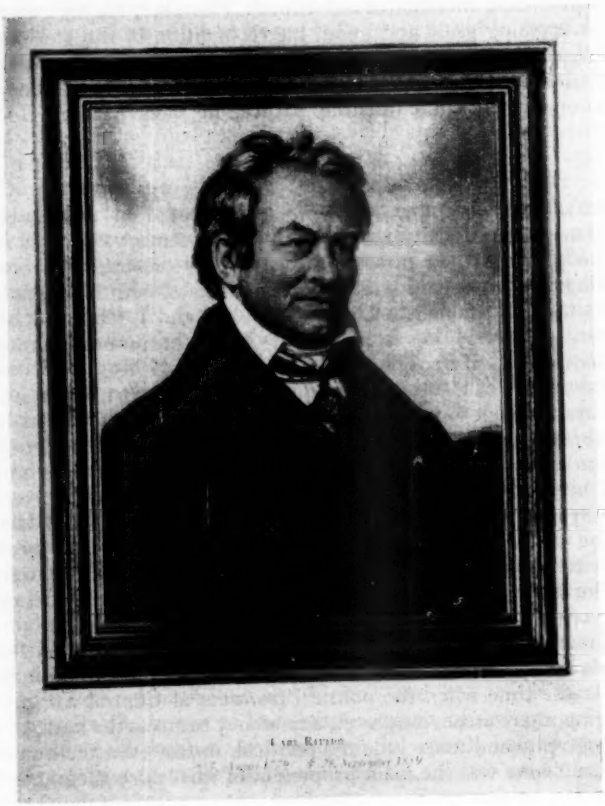
In the eighteenth century, geography was chiefly a registration of facts in compendia, which merely listed them for the practical purpose of administration and economics. At the time when the political frontiers of Central Europe were constantly changing, there arose, moreover, a tendency to stress the natural, permanent aspects of geography and to exclude the political, in fact even the human, aspects. Johann August Zeune was the main proponent of this 'pure geography', as it was called.

But under the influence of Johann Gottfried Herder, Ritter's thoughts turned most of all to the correlation of nature, on the one hand, and man and his history on the other. He tried to understand how all the phenomena of the earth's surface are connected, and regarded the earth as an organism, the continents and countries as units or 'individuals' held together by the relation of all the parts. The earth's influence on man he considered causal in the sense that the natural impulses of the earth's form affect man and civilisation.

But at the same time he was fully aware of the role of free will in man's actions. A deeply religious man, in the sense of Pietism, he saw all his work with young people and for science in the light of his Christian faith and as a service to God. This gave him a counterpoise to the determinism of Enlightenment as expressed by Montesquieu as well as by Herder. To Ritter, the earth seemed 'like a seed grain inwardly equipped with all the germ cells of growth and development, and thrown

by the Sower into the sun's orbit, there to germinate, to grow, to bloom and, in due time, to bear the fruit of its harvest.'

As early as 1810, in writing a review of an atlas by Heusinger, Ritter demanded a sort of Geography that would be 'a necessary part of human learning' and 'an elementary subject of education'. Moreover, he called for a geographical science that, 'starting out from the necessary, proceeds according to necessary laws inherent in its own nature, in order to arrive at a goal which only this science and no other power can portray and achieve in the same manner'.



Carl Ritter

Ritter's chief work was entitled *Geography in Relation to Nature and the History of Man, or General Comparative Geography as the Basis of Study and Instruction in the Physical and Historical Sciences*. Its first two volumes appeared originally in 1817 and 1818 and in a second edition in 1822. At Ritter's death in 1859, the work comprised nineteen volumes but, like Humboldt's *Cosmos*, was not completed. In modern terminology it might be called a broadly-planned handbook on human geography applied to the regions of the world. In writing it, Ritter used every source, from both ancient and modern literature on Africa and Asia. He was the first to attempt a description of the earth's surface in terms of regions, the peculiarities of individual regions, and the relation between such regions.

Thus, in a chapter on Arabia, for instance, he described not only the country

and its individual areas, its mountains, oases and cities, but also the physical appearance of the inhabitants, the nomadic way of life of the Bedouin and their relationship to the mountain peasants and oasis population, the folk character, the language and literature, the development of transportation by caravan, the people's history and the Wahabist movement, and finally the spread of the Arabs and Islam by land and water, as well as this people's position in the world.

Ritter never flagged in studying the connections between the earth's physical phenomena and Man's civilisation and industry, for instance the range of the monsoonal climate, the structure of mountain systems, or the spread and the history of cultivated plants and domesticated animals. It was Ritter who in a special treatise pointed out the genesis of the colonial plantation system, taking as an example the Arabian sugar cane estates with slave labour in the province of Khuzistan.

His subsequently much-criticised teleological outlook found expression, for instance, in a formulation in which he referred to the earth as 'the house for mankind's education'—a formulation that Herder made his own. In Ritter's teleology, the historical, geographical and pedagogical roots of his philosophy have been blended by his religious attitude. But his view, which fundamentally is metaphysical, never prevented Ritter from seeing causal and functional correlations.

Humboldt and Ritter held each other in high esteem; the feeling of Ritter, by ten years the younger, was deep admiration. Humboldt exercised the greatest influence on nineteenth-century exploration and on the growth of special branches of earth sciences; Ritter raised geography to the rank of a science, providing it with methodology and succeeding in making it an academic discipline. In 1820 he was given the chair of geography at the University of Berlin, a position he held until his death almost forty years later.

The year in which Humboldt and Ritter died has justly come to be regarded as the termination of the classical period of the science of Geography. At that time this science received decisive new impulses. In physical, biological and human geography the core of the new trends of thought was the idea of evolution.

During Humboldt's lifetime, geomorphology was still unknown. Only in 1841 did Carl Gustav Carus, a physician and landscape painter twenty years younger than Humboldt, proceed from the latter's idea of plant physiognomy and begin to refer to mountain physiognomy and the 'morphology of the earth's surface'. This was the starting point for geomorphology.

During the same year, Louis Agassiz, an enthusiastic admirer and disciple of Humboldt, propounded the theory that there had been an ice age or glacial epoch. The discovery of an ice age was to become an important factor in the doctrines of actualism as applied to the earth's history, a doctrine set forth by Adolf von Hoff after 1822 and developed by Charles Lyell in the 1830s. The existence of an ice age also gave an entirely new basis to prehistoric research. In terms of the methodical and theoretical attainment of new knowledge, the investigations on the glacial epoch during a century throughout the globe were the most successful achievement in earth research since the time of Humboldt, if only because it united numerous branches of science in a universal approach again—geology, geomorphology, soil science, climatology, paleogeography, biology, geophysics, prehistory and, in more recent times, even experimental physics in the field of isotope research as a method of geochronology.

Geological actualism was immensely enriched by Charles Darwin's theories. At the age of 22, in 1831, Darwin started his voyage on the *Beagle*, following in the footsteps of Alexander von Humboldt, and in the year of Humboldt's death published his theory of evolution. Only then was the time ripe, in the study of the physiognomy of organisms, to enquire into the proportion of hereditary,

constitutional characteristics and the proportion of the adaptational, or epharmonic, characteristics induced by environment. After Humboldt, the phytogeographers Anton Kerner von Marilaun, August Grisebach and Eugen Warming worked along these lines and initiated the doctrine of life forms.

In the spirit of positivistic thought, the idea of evolution, however, also took hold of the sciences concerned with man—sociology, history of civilisation, ethnology, and human geography. Human society in its correlation with environment was viewed by August Comte as an organism, and as governed by a law of development involving successive steps. Herbert Spencer's sociological concepts were even more influenced by biological ideas. Friedrich Ratzel's *Anthropogeographie* was based on thoughts the roots of which have, recently, been investigated by Johannes Steinmetzler and which clearly showed what a determining influence on human geography was exercised, after Ritter's death, by the biological theory of evolution on one hand and by positivistic sociology on the other. In 1868 Moritz Wagner, an outstanding zoologist and explorer, set against Darwin's theory of selection his own 'law of migration,' which gave a prominent place to the influence which the earth's history has had on the development of new species. The brisk exchange of thought between Wagner and Ratzel in Munich ultimately prompted the growth of the anthropogeography which, in accordance with the spirit of the time, was rather positivistic.

During the last few decades, human geography has grown beyond the limitations and errors of that period. Today, human geography seeks to understand the phenomena of civilisation and its economy by illuminating the phenomena of civilisation and its economy by illuminating the functional interplay of all the factors of demographical, social, and economic dynamics. Moreover, it seeks to determine the degree of influence exercised by physical conditions and by the course of history, in which the present is merely a momentary picture.

Despite all the progress that has been made in the sciences concerned with the earth in general and geography in particular during the last hundred years, we have every reason to feel awe and humility in the face of the universality of an Alexander von Humboldt, who was able to encompass everything known in his day about the earth and the universe, as well as before the sublime ethical and religious vision of a Carl Ritter, whose efforts were directed towards understanding the earth's peoples as invested by the Creator with a high destiny in the great diversity of their habitats and historic development.

For the very reason that the sciences are so extremely specialised today, we again feel the strong desire to view and understand the earth's phenomena 'in their general relationship, and nature as a whole, which moves and lives by indwelling forces', as Humboldt said. Certainly, specialisation is indispensable for the development of today's technical civilisation. But if at the same time there were no sciences seeking an all-encompassing view, in terms of both time and space, the intellectual sphere itself would be threatened by decay. Just as it must be the task of *history* as a science to understand the actions of mankind throughout the centuries on the basis of the intellectual and spiritual impulses that have gone out from social groups, modern *geography* seeks to comprehend the wonderfully manifold pattern of our terrestrial habitat on the basis of the interplay between natural phenomena and the historic phenomena of civilisations. By geographers, Alexander von Humboldt and Carl Ritter will always be celebrated as the auspicious twin stars in the firmament of our science.

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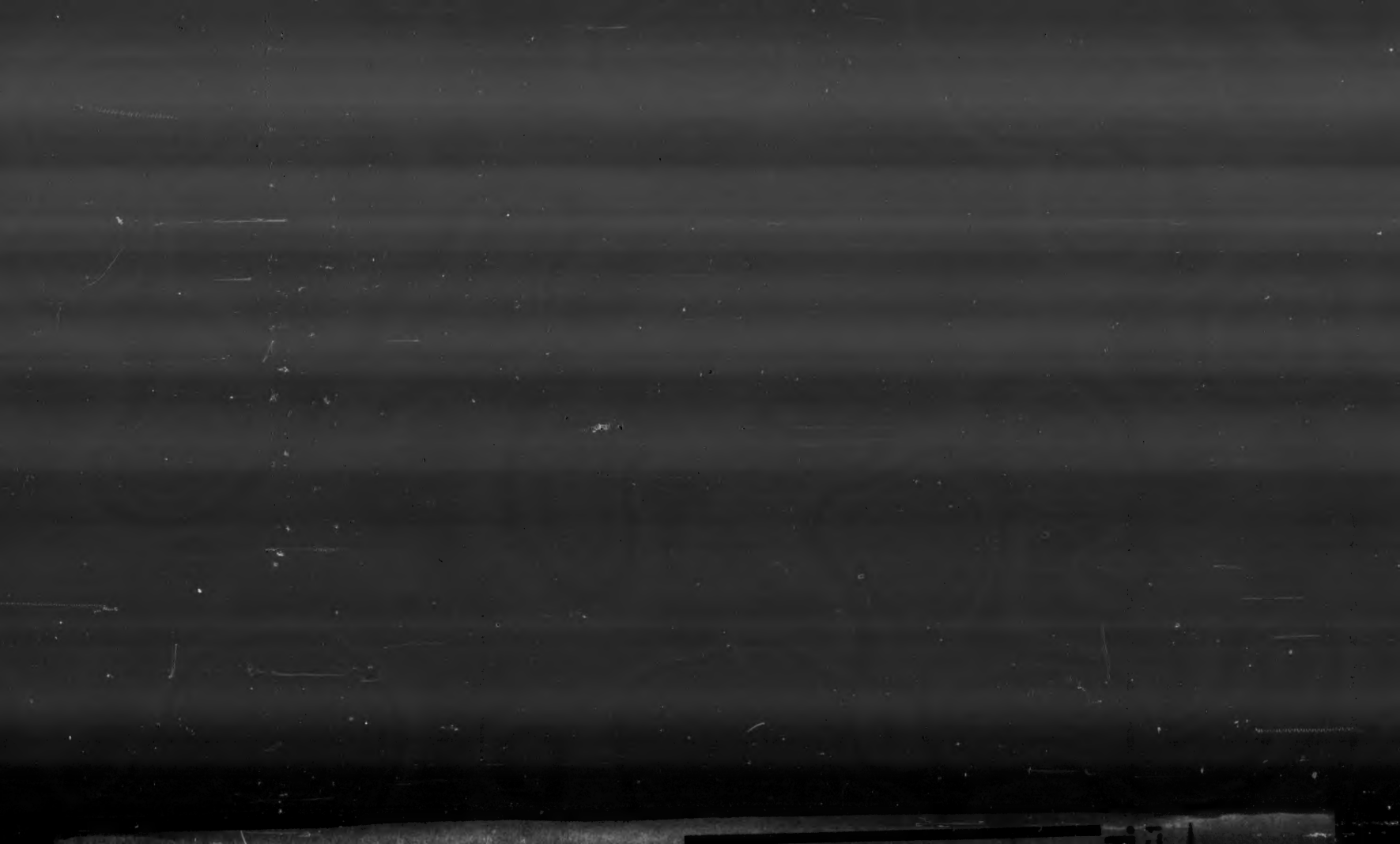
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